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Middlemen

IT is fashionable nowadays to give all the credit, and a good deal of the financial reward, to the man engaged on production work, and it is certainly a step in the right direction to realise the important part in the national economy played by the productive worker. There is, however, as so often happens, a tendency for the pendulum to swing too far, and for those not engaged in this type of work to be classed as liabilities. Far be it from us to advocate an increase in bureaucratic control—there is already much too great a tendency to approach a state of affairs in which one half of the population will be recording what the other half is doing—but there is a happy medium. There are those whose activities, whilst producing nothing, do assist the efficient distribution and utilisation of the products of our factories, and so contribute to the nation's prosperity, and the existence of a number of parasites should not blind us to the fact that many of these middlemen are performing a useful service. No one would suggest that we should deal directly with Tate & Lyle for half a pound of sugar, or with Unilever for a similar amount of margarine, and the same argument applies, with perhaps slightly diminished force, to the industrial field.

There is another aspect of the middleman question whose implication is technical rather than commercial. We refer to the link between research and the practical application of the results in industry. The Duke of Edinburgh, in his Presidential Address to the British Association referred to this matter when he said:—"As the front of pure science has advanced, so its lines of communication to practical exploitation have got longer and longer. The time was when the whole process of discovery, application, and exploitation could be achieved by one man. In our time a great army of scientists, technicians, inventors and designers, and production engineers are required to keep the lines of communication open. Quite how important some of the members of this follow-up team have become is not always appreciated. A more general and far-reaching matter for concern and possibly the most vital factor affecting the industrial application of scientific research is the lack of a co-ordinated system of scientific and technological education in this country. Excellent as they are, the existing institutions, which have grown up to meet particular circumstances, do not produce anything like enough trained technologists to meet the urgent needs of scientific development in industry and to provide leaders for the future. It is to be hoped that the new and rather uncertain science of education will develop sufficiently quickly to point the way to a speedy solution of this problem."

This shortage of technologists was dealt with in a recent survey of the scientific manpower situation in the metallurgical field. The conclusion reached was that there would be an overall shortage of metallurgists for some years, and that this would be most marked on the industrial side. In other words, the universities are turning out reasonably large numbers of men with a leaning towards research work, but comparatively few who are inclined to take up employment on the plant side and accept the responsibilities which such a step involves. In view of the necessity for bridging the gap between research and industry, however, the technologist is vitally important. The two sides do not always speak the same language and, without the services of an interpreter, the application of the results of research is going to be a slow business. It should not be inferred that we regard the technologist merely as an interpreter—a useful middleman, but one contributing nothing to development—for his training and experience are such that he can see more clearly than the research man or the industrialist the implications of new discoveries, and can contribute greatly in translating them into practical achievements.

At a recent conference of Directors of Research, it was suggested that considerable value could result from having a leavening of technically-trained men throughout the various non-technical departments of the company who could represent their departments on the committee considering the research programme. Approaching the question from the research department angle, another speaker emphasised the importance of having in the research department some members with knowledge and experience of what the production and commercial sides of manufacture involve. In his firm it was the practice for those engaged on a project in the research laboratory to follow it through to the full-scale production stage, except where the individuals concerned would be completely unhappy in so doing. In some cases a man proved to have a flair for plant management and stayed on production—in others they wished to return to the laboratory and begin again on fresh projects. This circulation of personnel does, however, ensure that the laboratory staff is made a little more aware of its real purpose in life.

Experience would suggest that not all who regard research as their vocation in life are correct in that view. True research must depend on ideas and ideas come from a comparatively few people. To be successful, a research department must have a reasonable number of people who by their ideas can inspire progress, and excessive dilution by misfits cannot be tolerated with impunity. To suggest that the misfits may provide a number of "technical middlemen" is not to disparage the latter—because a man is not the research type is no justification for assuming him to be unsuitable in other spheres. On the contrary it may be in his favour.

The only way in which the shortage of technologists will be satisfactorily overcome, however, is by an appreciation, by students, that production work can offer just the same challenge to initiative and ingenuity, as research work, and provide an equally interesting and probably fuller life.

Personal News

POWER Jets (Research and Development), Ltd., have appointed MR. G. C. R. MATHIESON, B.Sc., D.R.T.C., to be Senior Lecturer at the School of Gas Turbine Technology, Farnborough, Hampshire.

MR. L. A. C. BARTLETT, A.M.I.Mech.E., and MR. W. A. H. MAY, M.C., have been appointed to the Board of George Kent, Ltd. Mr. Bartlett has been with the firm for 25 years, entering as an apprentice, whilst Mr. May, who is a great-grandson of the Founder of the firm, joined George Kent, Ltd., in August, 1938, as Personnel Manager.

SAMUEL OSBORN & Co., Ltd., Clyde Steel Works, Sheffield, announce that MR. F. A. HURST has been elected Chairman of the Company following the death on July 19th, of Mr. S. Eric Osborn. Mr. Hurst has had a wide experience in the various aspects of Osborn's activities, and has been a Managing Director since 1923.

THE Committee representing the Royal Society and the University of Sheffield has appointed DR. B. A. BILBY as Sorby Research Fellow from October 1st, 1951, to work in the Metallurgy Department of the University of Sheffield on martensitic transformation and deformation twinning in crystals.

THE Committee representing the Royal Society and the Armourers and Brasiers' Company has appointed DR. A. J. KENNEDY Armourers and Brasiers' Company Research Fellow from October 1st, 1951, to work at the Royal Institution of Great Britain on transient creep in polycrystalline metals.

MR. J. L. HARRISON has joined the British Oxygen Co., Ltd., in advisory and consultative capacity on matters concerning the use of oxygen in steelmaking processes. While serving with Catton & Co., Ltd., of Leeds, he was concerned with the development of oxygen-enrichment of side-blown converter blast.

MR. J. MCCRACKEN has left Stewarts Lloyds, Ltd., to become General Manager with the Indian Iron and Steel Company, Ltd., and the Steel Corporation of Bengal.

MR. A. L. STOCK has been appointed Managing Director of The Morgan Crucible Co., Ltd., in succession to the late Mr. H. C. Mills.

Fellows of the Institution of Works Managers

FELLOWS of the Institution of Works Managers are "men of distinction in the practice of works management." The Council of the Institution invites not more than fifteen members to become fellows each year, so that the honour is a rare one and is valued highly. For 1950–1, the following members have accepted invitations to become fellows :—

R. W. BAILLIE, Director and General Manager, South Durham Steel and Iron Co. Ltd., Stockton-on-Tees.

L. C. BAXTER, General Manager, Hockley Chemical Co. Ltd., Birmingham.

J. BAYLISS, Director and General Manager, Birmingham Steel Co. Ltd., Tipton, Staffs.

S. R. EADE, M.I.E.E., Manager of Lamp Factories, B.T.H. Co. Ltd., Rugby.

J. M. ELLIS, Factory Manager, J. Lyons and Co. Ltd., London, W.14.

J. S. FARNWORTH, General Manager, (Plant Division), Buckton, Ltd., Stockport.

E. C. R. GRANT, General Manager, Osram–G.E.C. Ltd., London, W.6.

P. GROVE, Director, Tube Investments, Ltd., Birmingham.

L. G. HENRY, General Manager, Remploy, Ltd., London, S.W.1.

A. W. C. MCARTHUR, M.I.E.E., Director and Works Manager, W. T. Henley's Telegraph Works Co. Ltd., London, E.16.

C. W. MUSTILL, M.B.E., M.I.Mech.E., M.I.Prod.E., Works Director, Jackson Boilers, Ltd., Leeds.

D. G. PETRIE, M.I.Mech.E., Vice-Chairman and Production Director, Star Paper Mills, Ltd., Feniscowles and Senior Partner, Management Engineers, Ltd., London, W.1.

W. ROBINSON, Works Manager, Ferranti, Ltd., Manchester.

A. SCHOLES, A.T.I., Works Manager, British Enka, Ltd., Liverpool.

J. B. STEADMAN, J.P., Joint Managing Director, Derham Bros. Ltd., Bristol.

Obituary

WE regret to record the following deaths :—

MR. SAMUEL ERIC OSBORN, Chairman of Samuel Osborn and Co., Ltd., who died in London on July 19th, following an operation. He was 59. Mr. Osborn was the only son of the late Mr. Wm. Fawcett Osborn and a grandson of the founder of the Company which he joined in 1910.

MR. JOHN DIXON BRUNTON, Managing Director of Bruntons (Musselburgh), Ltd., who died on July 5th, at the age of 79.

MR. H. C. MILLS, Managing Director of The Morgan Crucible Co., Ltd., of London, S.W.11, who died suddenly on June 27th.

Realise on Your Waste Paper

THE post-war years have seen increasing apathy towards the salvage of many scrap materials. There are, of course, notable exceptions for, as is well known, the remarkable output figures of the steel industry for the last few years would have been impossible of attainment had not the recovery of scrap iron and steel been vigorously prosecuted. Our national prosperity depends on a revival of "salvage-consciousness" and this is particularly true of paper. The output of packaging material, on which every industry depends, is slowing down, and many manufacturers are already feeling the pinch. In 1950, the total amount of waste paper salvaged and returned to the mills for re-pulping was 847,055 tons, but the total consumption was 887,082 tons. This year the rate of consumption has reached the figure of 1,000,000 tons and more is needed. The deficit has already affected a large number of industries and the situation will deteriorate still further unless more waste is forthcoming. Waste paper merchants are prepared to buy waste from large business houses and manufacturing firms, and its monetary value to-day, provides an added reason for returning it to the mills via the waste merchant. Information as to the location of your local waste paper merchant can be obtained from the Waste Paper Recovery Association at 52, Mount Street, London, W.1.

The Heat Treatment of 3% Nickel-Chromium Case-Hardening Steel

By H. D. Mansion,* M.Sc.(Eng.), A.C.G.I., A.M.I.Mech.E.

The following article gives the results of a laboratory investigation into the heat treatment of two samples of En.36 nickel-chromium case-hardening steel by various methods. Small test bars, all carburised as one batch, were given single and double quenching treatments and, finally, a stress relieving treatment, the hardnesses and metallurgical structures being studied at each stage. The object of the investigation was to furnish information on which to base the choice of heat treatment for a batch of test gears which was being made from the same material. It will be seen that the main effect of the so-called "core refining" treatment (i.e., the first quench) is to diffuse the cementite network of the carburised case, the core structure and strength being apparently little affected as compared with those of single-quenched specimens.

IN the course of an investigation at the Motor Industry Research Association into the bending fatigue strength of gears manufactured by different gear-cutting and gear-grinding processes, it became necessary to decide upon a suitable heat treatment for the 3% nickel-chromium case-hardening steel used. This was to British Standard Specification En.36†, in the form of up-ended drop-forgings of two different analyses.

Enquiries within the automobile industry as to the heat-treatment practice adopted for transmission gears made from similar alloy case-hardening steels indicated that some manufacturers preferred to give, after carburising, a single re-heat and oil quench, with no stress-relieving or tempering treatment at all, while other manufacturers insisted on giving the conventional double oil quench treatment followed by tempering at some temperature between 120° and 180° C.

The above specification, En.36, calls for the following heat treatment to be given to $1\frac{1}{8}$ in. dia. test bars after carburising :—

"Refine at a temperature of 850°/880° C., cool in air, oil or water

"Harden in oil from a temperature of 760°/780° C."

and includes provision, in certain cases, for the adoption of a single-quench treatment from 760°/800° C.

The choice of refining cooling medium, and of quenching temperature for the single-quench treatment, appeared rather wide, so, whilst it was appreciated that both the size of the work and the actual steel analysis were important factors in determining the optimum treatment, a laboratory investigation on small cylindrical test pieces of the same materials was undertaken to find what effect these variables had on the hardness and on the metallurgical structure of the finished product.

In presenting the results of this laboratory study no claim is made to be adding to basic metallurgical knowledge, but it is hoped that they will prove of interest to engineers who are faced with the problem of heat-treating gears and of interpreting photo-micrographs of their metallurgical structures.

* Motor Industry Research Association.
† B.S.S. 970: 1947 "Wrought Steels: En Series"

Materials

Gear blanks and corresponding test bars were available from each of two different sources, their analyses being as shown in Table I.

For the present investigation a $\frac{3}{4}$ in. dia. bar was turned from each material, and divided into sections as shown in Fig. 1, each section comprising either two or three $1\frac{1}{2}$ in. test pieces which were numbered as indicated. Fig. 2 shows the structure of one of the forged test bars as received.

Carburising

All the sections were packed in a box surrounded by an activated charcoal compound and carburised at 900° C. The furnace load took about 2 hours to come up to temperature and was then given 6 hours soaking time, the box being left in the furnace (a small laboratory type) to cool off. The case depth obtained was about 0·047 in. in steel A and 0·044 in. in steel B, the microstructure of core and case after carburising appearing as in Fig. 3. In the subsequent study, Vickers hardness tests were made at each stage of the proceedings on both types of steel, and photomicrographs were made of steel A only. The hardness values are given in Table II.

Heat Treatment

The two specimens marked "1" in each steel were refined by heating for half an hour at 860° C. in a muffle furnace followed by cooling in still air, which gave a structure as shown in Fig. 4. (Note the similarity of this "normalised" core structure to that of the original bar, Fig. 2). The specimens marked "2" were given a similar soak for half an hour at 860° C., and then quenched in mineral oil at room temperature, which gave the structure shown in Fig. 5. (The core is now hardened, but the case is very similar in appearance and in hardness to that of the air-cooled specimens). The specimens

TABLE I.—CHEMICAL COMPOSITIONS OF THE TWO STEELS TESTED

Steel	C	Si	Mn	S	P	Ni	Cr	Mo
A	0·11	0·25	0·44	0·010	0·010	3·45	1·03	—
B	0·14	0·19	0·47	0·016	0·035	3·19	0·92	0·19

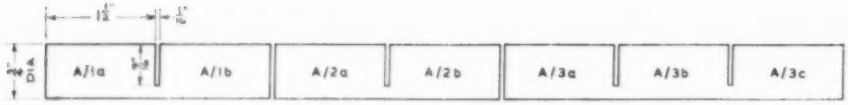
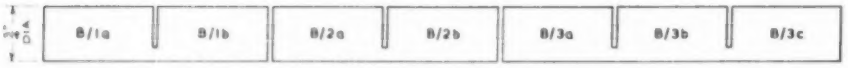


Fig. 1.—Method of preparing and designating test specimens.



marked " 3 " were not given any refining treatment, but were set aside to be hardened by a single oil quench.

The various groups of specimens, as shown in Fig. 1, were now broken apart into individual test pieces, a comparison of the fractures of the air-cooled and oil-quenched specimens being shown in Fig. 6. All pieces were then hardened by quenching in cold oil; those

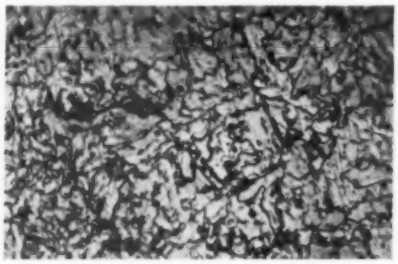


Fig. 2.—Forged bar, A, as received. × 450

marked " a " from 760° C., and those marked " b " from 780° C., and the two marked " c " from 800° C. The hardness of all specimens was measured and the microstructures of those in steel A examined, see Figs. 7 to 13.

A word of explanation is necessary about the actual condition of each specimen when examined at this stage. The hardness was measured on the bars as hardened after polishing off the scale. The case and core structures, however, were photographed from specimens (cut from the $1\frac{1}{2}$ in. long bars by grinding) which had been mounted in bakelite slugs to facilitate polishing the edges. The bakelite available required to be moulded for 15 minutes at 170° C., so it must be borne in mind that the samples photographed had been tempered at this temperature. This may have resulted in some darkening of the martensitic structure, but will not have affected the distribution of carbides in the case.

As a final step in the heat treatment, the specimens in steel A were tempered in air for 1 hour at 185° C., and those in steel B for 2 hours at 160° C. The hardness of case and core after each of these treatments was again measured.

Discussion

On studying the hardness figures given in Table II those obtained after hardening and before tempering indicate that the lowest quenching temperature, 760° C., gives the highest case hardness, and that this value is not influenced by the method of refining, although the omission of the refining treatment, as on specimens A/3a and B/3a, gives a slightly less hard case. An increase in hardening temperature to 780° C. gives a reduction in case-hardness rather greater in steel A than in steel B (except for the single-quenched specimens), while a further increase to 800° C. as a single-quench treatment gives a further substantial reduction in case hardness in both steels.

It will be noted, however, that the 780° C. quench, whilst giving, in general, a softer case than the 760° C. quench, gives a harder core in almost all instances, though this effect is barely noticeable in the single-quenched specimens. The further increase in hardening temperature to 800° C. for the single-quenched specimens gives no further increase in core hardness, so is evidently not beneficial from the hardness point of view. The change from air-cooling to oil-quenching as a refining treatment gives a negligibly small reduction in core hardness in steel A but an increase in hardness of 10 to 20 points in steel B; however it would seem doubtful if this small increase were worth while if accompanied by additional quenching distortion.

Turning to the tempering or stress-relieving treatment, the marked reduction in surface hardness of the A specimens, from about 800/840 V.P.N. to 700/720 V.P.N., resulting from tempering at 185° C., suggests that this was considerably too high a tempering temperature for general purposes. The reduction in hardness of the B specimens by about 60 to 85 points, resulting from tempering at 160° C., was more reasonable and it is of interest to note that two of the specimens which were previously tempered at 140° C. had been only slightly less affected.

Thus by the criterion of core and case hardness alone

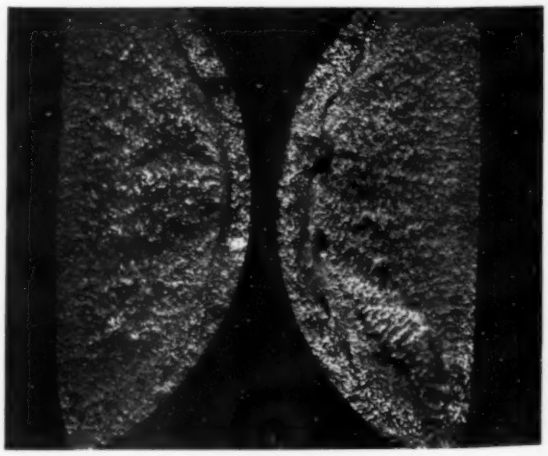


Fig. 6.—Fractures after refining, × 4·5. Left in air, right in oil.

CORE CASE

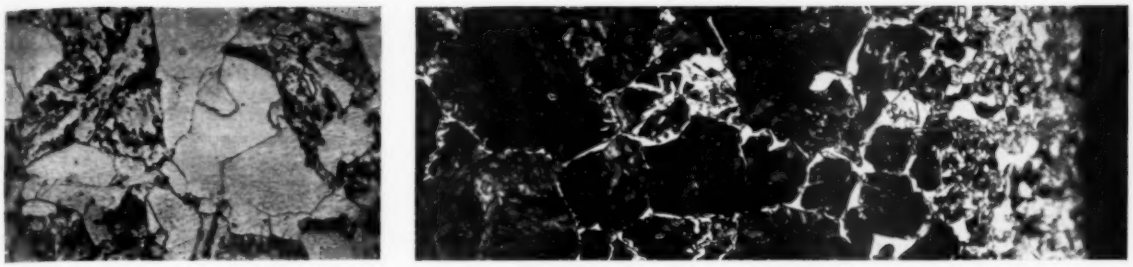


Fig. 3.—After carburising. × 450

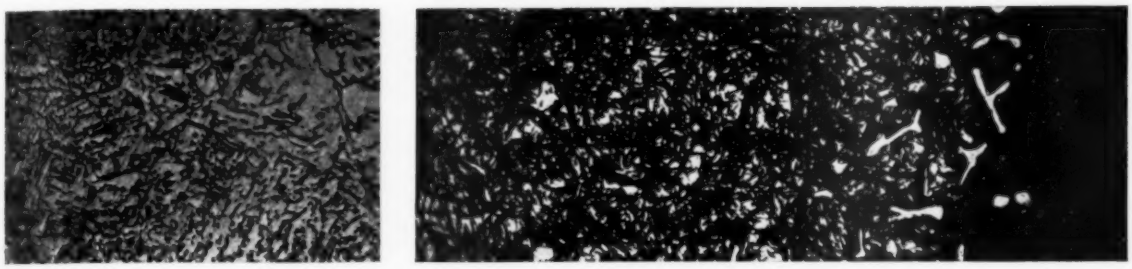


Fig. 4.—Section A/1, refined by air cooling from 860° C. × 450

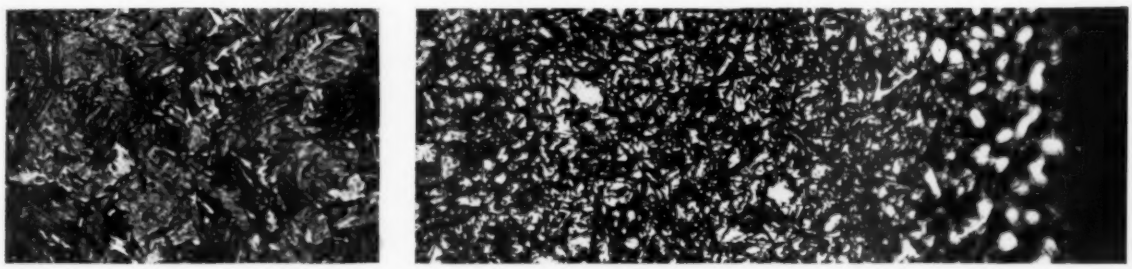


Fig. 5.—Section A/2, refined by oil quenching from 860° C. × 450

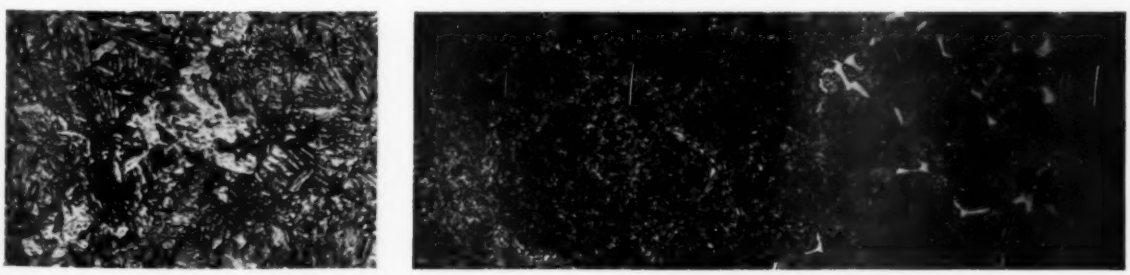


Fig. 7.—Specimen A/1a ; 860° C. air cool, 760° C. O.Q. × 450

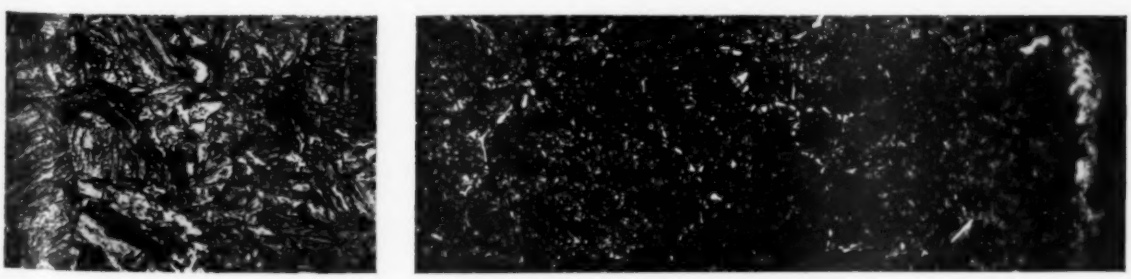


Fig. 8.—Specimen A/1b ; 860° C. air cool, 780° C. O.Q. × 450

TABLE II.—HEAT TREATMENTS AND RESULTANT HARDNESS VALUES

(Case hardness in bold type, core hardness in normal type)

Specimen No.	Carburise		Refine			Harden (Oil Quench)			Temper (Stress Relieve)		
	Time	Temperature	Soaking time	Temperature	Hardness, V.P.N.	Soaking time	Temperature	Hardness, V.P.N.	Soaking time	Temperature	Hardness, V.P.N.
A/1a	2 hrs. heating 6 hrs. soaking Cooled in furnace Case depth 0·047 in.	900° C.	½ hr.	860° C. Air cool	**730** 265	½ hr.	760° C.	**842** 336	1 hr.	185° C.	**718** 347
A/1b						½ hr.	780° C.	**805** 362			**706** 362
A/2a			½ hr.	860° C. Oil quench	**702** 379	½ hr.	760° C.	**840** 332			**718** 335
A/2b						½ hr.	780° C.	**802** 365			**697** 364
A/3a			No refining treatment		**433** 200 As carburised	½ hr.	760° C.	**829** 361			**725** 355
A/3b						½ hr.	780° C.	**798** 363			**712** 356
A/3c						½ hr.	800° C.	**746** 360			**677** 359
B/1a	2 hrs. heating 6 hrs. soaking Cooled in furnace Case depth 0·044 in.	900° C.	½ hr.	860° C. Air cool	—	½ hr.	760° C.	**849** 316	2 hrs.	160° C.	**760*** 322
B/1b						½ hr.	780° C.	**827** 328			**756** 300
B/2a			½ hr.	860° C. Oil quench	—	½ hr.	760° C.	**845** 326			**778*** 328
B/2b						½ hr.	780° C.	**835** 348			**741** 341
B/3a			* No refining treatment		**387** 182 As carburised	½ hr.	760° C.	**831** 324			**769** 318
B/3b						½ hr.	780° C.	**796** 331			**734** 329
B/3c						½ hr.	800° C.	**749** 333			**715** 335

* These two specimens were first tempered for 2 hrs. at 140° C., giving case hardnesses of 781 and 787 V.P.N., respectively.

there would appear to be little benefit to be gained by giving a refining heat treatment to this type of steel, but a study of the photomicrographs shows where the benefit of refining is to be felt. The microstructures, Figs. 7 to 10, of all specimens which have received the double heat treatment show that the cementite network in the grain boundaries, although still generally traceable, has to a large extent been broken up and diffused, whereas this network is still all too clearly present in the two specimens single-quenched at 760° and 780° C., respectively, Figs. 11 and 12. In the third single-quenched specimen, Fig. 13, quenched from 800° C., the network has already been considerably broken up, but the main case structure has become very much coarser with more retention of austenite and a considerable drop in hardness. Fig. 5, showing the structure after oil quenching from 860° C., really forms a fourth stage in this series of single-quenched specimens. At this temperature the cementite is almost entirely diffused or spheroidised, but much more austenite is present and the case hardness is still further reduced. It will be noted that the core structure is apparently quite insensitive to the final quenching temperature, whether previously refined or not, although the core hardness does increase, up to a point, with increase in quenching temperature.

It would appear therefore that the so-called "core refining" treatment is of much greater value as a "carbide-diffusing" treatment than for actual refining of the core structure, and the results of the present investigation confirm an impression gained some years ago at the M.I.R.A. Laboratory that for full diffusion of the carbide network an even longer soak at the refining temperature is necessary.

After considering the above results, it was decided that the most suitable treatment for the test gears, then being made from steel A, would be that given to Specimen No. A/1b., viz—, refining by air cooling from 860° C., followed by hardening in oil from 780° C. It appeared that a good hard case (over 800 V.P.N. before tempering) could be expected, together with a fully-hardened core of about 360 V.P.N. A tempering temperature of 150° C. was decided upon to avoid unduly reducing the above case hardness.

The resultant gears appeared fully to justify the choice of treatment. A case hardness of approximately 777 V.P.N. on the tooth profiles was obtained after tempering, together with a core hardness of 358 V.P.N. in the massive body of the gear and 400 V.P.N. near the root of a tooth. Fig. 14 shows the microstructure of a tooth of one of these gears taken near the mid-section and approximately on the pitch line, and it is interesting to note that no intercrystalline network of carbide remains.

The value of the diffusion period at a fairly high temperature does not always appear to be fully appreciated by heat treaters, although those using the gas-carburising process, both in Britain and in the U.S.A., generally appear to allow for it.

As an alternative to the double heat treatment, it is suggested to those, for whom heat-treatment economics are of primary importance at all times, that both furnace time and fuel might be saved by removing the carburised parts from their boxes while still at carburising temperature and returning to a furnace at, say, 860°–900° C., preferably with a neutral atmosphere, where, with a suitable holding time, carbide diffusion could take place,

CORE CASE

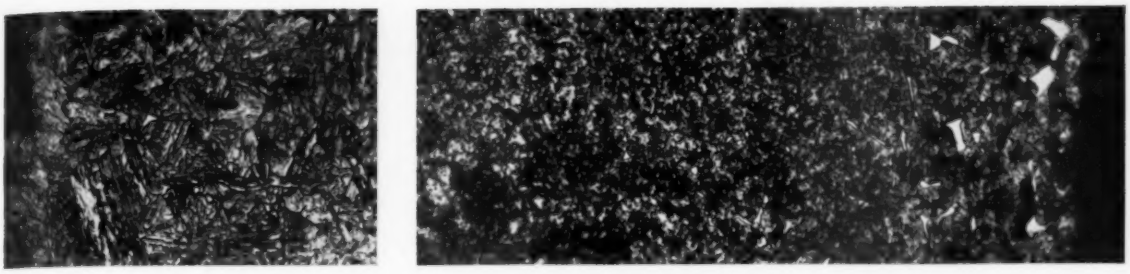


Fig. 9.—Specimen A/2a ; 860° C. O.Q., 760° C. O.Q. × 450

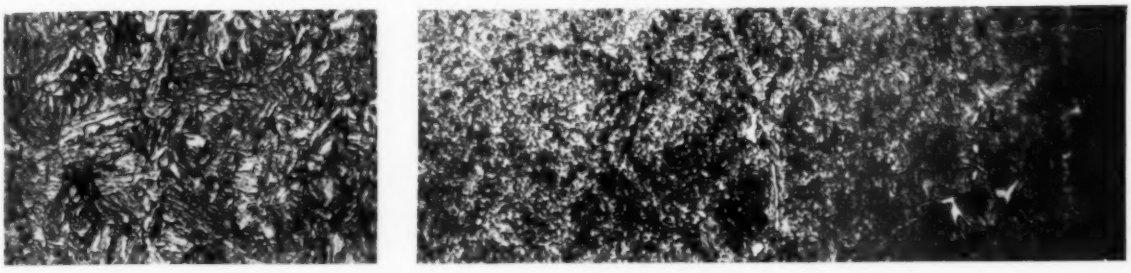


Fig. 10.—Specimen A/2b ; 860° C. O.Q., 780° C. O.Q. × 450

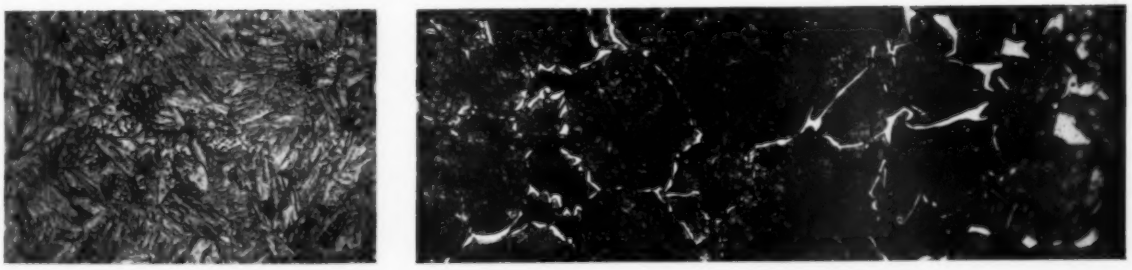


Fig. 11.—Specimen A/3a ; single heat treatment, 760° C. O.Q. × 450

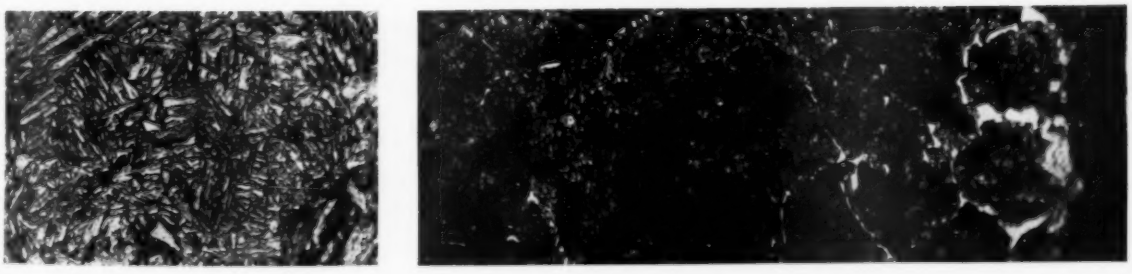


Fig. 12.—Specimen A/3b ; single heat treatment, 780° C. O.Q. × 450

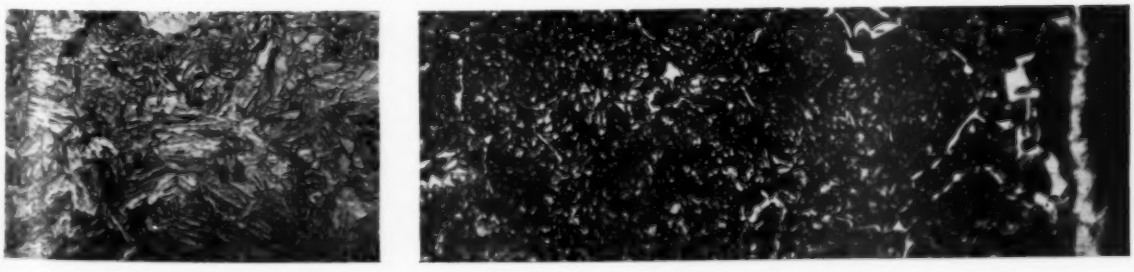


Fig. 13.—Specimen A/3c ; single heat treatment, 800° C. O.Q. × 450

CORE CASE

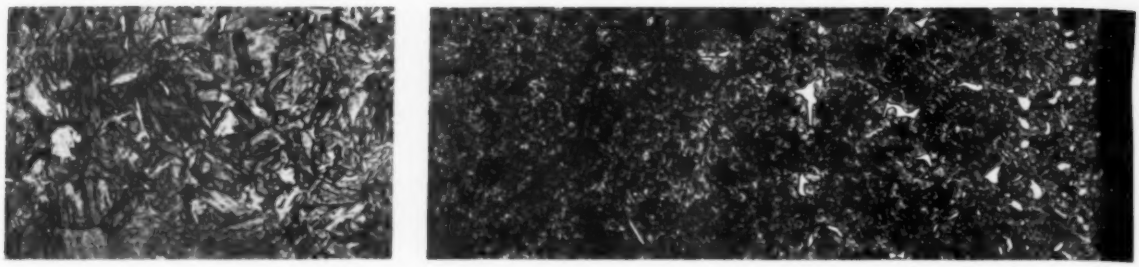


Fig. 14.—Actual gear tooth made from Steel A; 860° C. air cool, 780° C. O.Q., 150° C. T. × 450

prior to air cooling and subsequent re-heating for a hardening treatment consisting of oil quenching from a suitable temperature.

The author wishes to express his thanks to the Motor Industry Research Association for permission to publish this article.

Johnson Matthey Progress

At the Annual General Meeting of Johnson, Matthey & Co., Ltd., held on July 30th, the Chairman, Mr. Hay W. P. Matthey, said that although traditionally known for its work on assaying and refining the precious metals, its stamp on gold and silver bars being accepted all over the world as a hall-mark of quality, the Company now covered a wider field and manufactured and distributed the precious metals in whatever form they were required by a wide range of industries. Mr. Matthey then referred briefly to various aspects of the Company's activities, dealing first with the refining of the precious metals.

Precious Metals

There has recently been completed the largest building project undertaken by the company for many years in the erection and the bringing into full operation of the extension to the platinum treatment works at Brimsdown, at a cost of approximately £800,000. The Brimsdown works are designed for the treatment of the platinum-bearing nickel-copper matte arising from the smelting in South Africa of concentrates produced at the Rustenburg and Union Platinum Mines. While the extension to the works was in process of being built, there was inevitably an accumulation of untreated platinum-bearing material, but the arrears have been overtaken and the plant is now keeping pace with the greatly increased rate of production from the mines. The chief products from the Brimsdown works are refined nickel, refined copper and a platinum group metal concentrate. This latter material is subsequently treated in the Company's refineries at Hatton Garden.

Owing to the continuing heavy demand for platinum, further large scale expansions have been decided on at the Rustenburg and Union mines, resulting in increased quantities of nickel-copper matte requiring, as a first step, to be treated for the extraction in pure form of nickel and copper. It is intended that this additional matte shall be treated in South Africa, and for this purpose Johnson Matthey are joining with Rustenburg Platinum Mines, Ltd., on terms of joint ownership, in the erection of a treatment plant at Rustenburg in the Transvaal. The final refining of the platinum group metals will be carried out in England.

The gold refineries have been very active during the last year and the refining of silver has also been maintained at a high level. Among the material treated has been demonetised coinage of the United Kingdom as well as that of New Zealand, Southern Rhodesia, Malaya and other countries.

Engineering Demands

Sales to the engineering industries during the past year were greater in volume than in any previous year. Increases have been most marked in the quantities supplied of low-temperature silver brazing alloys, of electrical contacts in silver and platinum and their alloys, and of precision drawn base metal tubes and fine wires, mostly for the electrical, electronic and instrument industries. The output of machined and pressed parts for electrical contacts and allied components now exceeds three million a week, while over a million feet a month of precision drawn tubing are being steadily produced.

Silver continued to be in demand for chemical plant, and a variety of items of process plant fabricated in this metal have been produced during the year. Among others, the Company was again called upon to make during the year one single piece of silver for the eventual production of a tubular vessel, the initial casting weighing just over two tons. There has also been a very heavy demand for platinum in various manufactured forms for use in chemical plant of one kind and another.

The photographic, pharmaceutical and glass silvering industries have maintained at their previous high level their purchases of silver nitrate, and sales of other precious metal compounds, particularly for use in the electro-plating trade, were satisfactory.

There has been progress which seems likely to continue even further in the production of spectrographically pure substances, and the output of a number of base and minor metals in a state of exceptionally high purity has been greatly increased. The rare element germanium, for instance, hitherto separated on so minute a scale as to be of no more than academic interest to metallurgists, is now being produced on a commercial scale, and is playing a small but important part in the defence programme.

Britain's Newest Steelworks Opened

Steel Company of Wales Project Materialises

Of the recommended expenditure of £240,000,000 on post-war reconstruction schemes for the iron and steel industry, it was suggested that no less than £60,000,000 should be devoted to a single project in the South Wales sheet steel and tinplate industry. The seal was set on this great enterprise when the Chancellor of the Exchequer formally opened the modern integrated works of the Steel Company of Wales at Port Talbot last month. Given suitable raw materials the plant will produce 30,000 tons of steel per week, to roll into 3,500 tons of railway material and 22,800 tons of strip and plate.

ON July 17th, by the touch of a lever, Mr. Hugh Gaitskell released a slab to the finishing mill and so formally opened the new Abbey Works of the Steel Company of Wales. When the associated cold reduction plant comes into operation later in the year, the country's capacity for sheet steel production will be increased by 20%, whilst the new plant at Trostre, which is a further part of the scheme, will add as much as 70% to tinplate production capacity.

It had been hoped that His Majesty the King would have been able to perform the opening ceremony, but his continued illness had compelled him to decline the invitation. In a message to Mr. E. H. Lever, Chairman of the Company, His Majesty said :

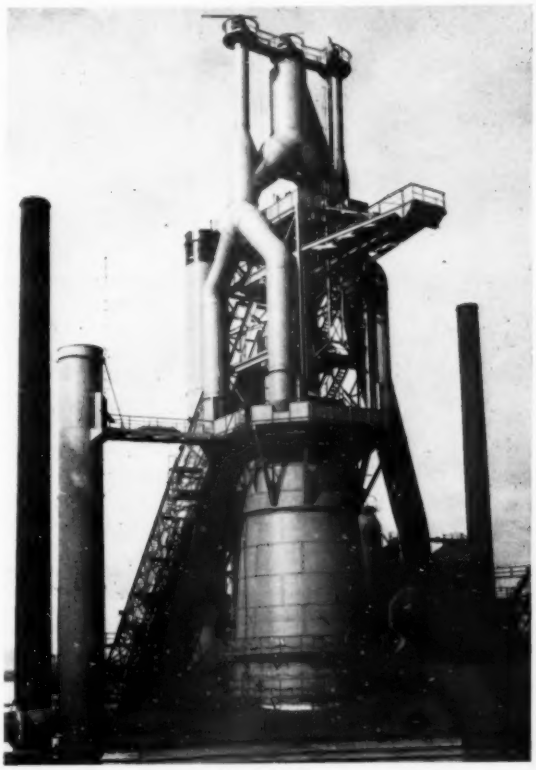
"Please convey my sincere good wishes and those of the Queen to all who work at Port Talbot and Llanelly, and to all your guests assembled at luncheon to-day to celebrate the inauguration of your new steel works.

"I recall my visit seven years ago and I greatly regret that for the time being I am unable to inspect for myself the important developments for which your Company is responsible.

"I rejoice, however, to know that by your efforts, and with the generous help of our friends the American people, it has been possible to complete the equipment of this plant which will make so valuable a contribution to the welfare of our country and to our ability to maintain our historic position in a free world."

Mr. Lever said that while they were naturally disappointed at the absence of Their Majesties, their only concern was that His Majesty should speedily be restored to complete health. In recognition of His Majesty's interest and understanding of their problems, the directors, staff and workpeople were, with his gracious consent, sending him a memento of the occasion. It took the form of an iron key, recovered from the depths of sand dunes covering an old grange of Margam Abbey during the preparation of the Abbey Works Site.

In proposing the toast of the Chancellor, Mr. Lever said, "Four years ago we accepted a challenge. At a time when this country was no longer as rich as it had been, we said that we would bring it again into the front rank of production within our own province. Our province is steel—sheet steel and tinplate to be precise—and we determined that we would point the way to economic recovery throughout Great Britain. We were not idly boasting. It was not a sudden romantic decision: it was a decision founded on quiet work that had been done even while the desperate battles for our liberty were still being fought, and what you see to-day is the product of that early preparation and of our abiding faith, even in the darkest days in our recent history, that the future is not only worth fighting for but worth working for."



No. 2 blast furnace at Margam Works.

Mr. Gaitskell, in reply, said that four years ago the economic prospect was hard and bleak and cheerless, as was also the site of the Abbey Works at that time. The Steel Company of Wales had changed all that as was evident from a survey of the landscape. After emphasising that it was in sheet steel and tinplate that the greatest shortages had been since the war, the Chancellor continued : "I am told that when full production is achieved the strip mill at Abbey Works will produce well over a million tons of steel a year, and this may possibly become two millions, most of it to be further rolled into sheet and tinplate in the new cold reduction plants at Abbey Works and Trostre. There will come from these works, on the most conservative estimates, no less than 300,000 tons of cold-rolled steel sheet and 305,000 tons of tinplate." After paying tribute to those who had taken part, in whatever capacity, in the preparation of the site, the erection of the vast and

New conveyor system at Margam Works.

splendid buildings, and the installation of some of the most efficient machinery known to the modern world, Mr. Gaitskell acknowledged the help received from America. Certain equipment had to come across the Atlantic and Marshall Aid found the dollars to pay for it. In conclusion Mr. Gaitskell said, "The contribution which you will all make to meet the nation's needs will, I am sure, fully match the courage and foresight, skill and hard work, which built these great works."

History of the Project

The Steel Company of Wales was formed when four great companies engaged in the steel and tinplate industries pooled their resources and their knowledge in order to make what is probably the greatest single contribution to British industry to-day. For many years South Wales has been the home of British tinplate but even to-day 70% of the tinplate produced in Wales is made by the old pack mill method, which, though it calls for a high degree of skilled work, is slow and costly. Modern experience has proved beyond all doubts that the continuous strip mill is superior not only in speed of production but in uniformity and operational economy, and long before the war it was obvious to all who were engaged in the industry that only the building of a wide continuous strip mill in South Wales could really put the industry back on its feet and enable it to maintain its place in the competitive markets of the world.

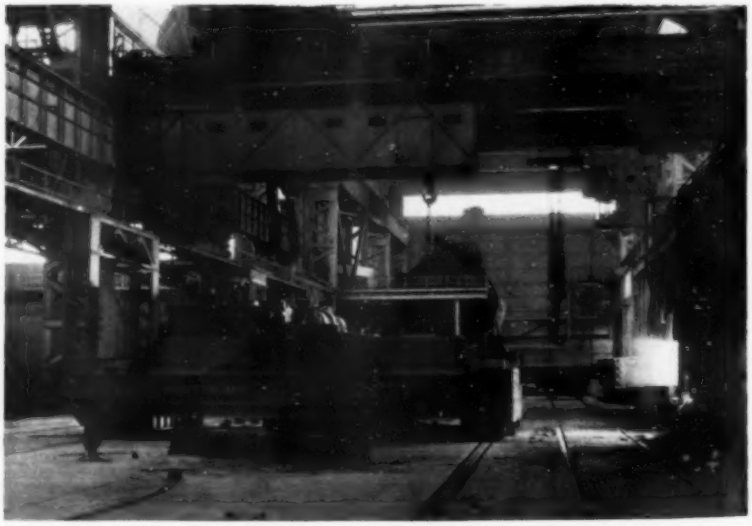
After the war the Iron and Steel Federation presented to the Minister of Supply plans for the reconstruction projects under consideration throughout the steel industry of the country. The board recommended that projects to the extent of £240,000,000 should be approved and that of this sum £60,000,000 should be for a reconstruction project in the South Wales sheet steel and tinplate industry. It was universally considered that the task of reconstruction required was beyond the resources of any individual group and an amalgamation was therefore formed between four of the largest companies engaged in the industry. It was this amalgamation which led to the formation of the Steel Company of Wales. Under the chairmanship of Mr. E. H. Lever, the four founder companies—Guest Keen Baldwins, Richard Thomas & Baldwins, John Lysaght, and the Llanelly Associated Tinplate Companies—pooled certain of their resources calculated at a value of more than £10,000,000, including a steelworks at Port Talbot and Margam, 18 tinplate works in West Wales, and a sheet works at Newport.

The plan was to reconstruct and enlarge the blast furnaces, coke ovens and coal and ore handling plant at the Margam Steelworks, in order to cater for the greater production of pig iron required, and to erect adjacent to the Margam Works a new 80-in. continuous strip mill, together with a melting shop and ancilliary plant, making one integrated works which would, when completed, extend for 4½ miles, and the estimated steel production of which would be 1,500,000 tons of ingots per year.

As an integral part of the scheme there were to be two cold reduction mills and a modern tinplate plant. One of these cold mills was placed alongside the continuous mill at Margam, while the other, together with the tinplate plant, was located at Trostre, near Llanelly.

Reconstruction at Margam Works

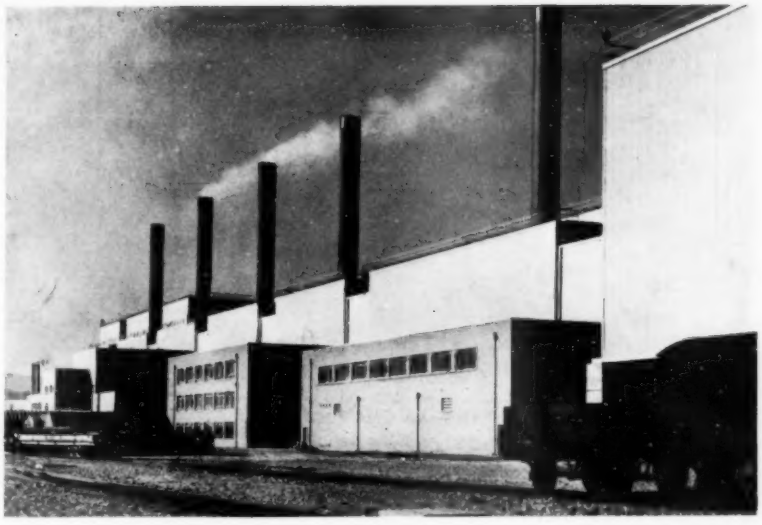
It was no easy matter to carry out the extensions to the existing Margam Works without interfering with the



Charging machine at Margam melting shop with mixers in background.

process of production. The effectiveness of the planning and the high degree of co-operation forthcoming from all departments is shown by the fact that while the reconstruction has been in progress every production department has steadily increased its output.

In order to provide sufficient pig iron to feed the Abbey melting shop, in addition to those at Port Talbot and Margam Works, the blast furnace plant has been considerably enlarged. Following an examination of the site conditions, the foundations of the blast furnaces were taken down to ballast strata, at a depth of about 20 feet, and spread so as to achieve a maximum loading of 2½ tons/sq. ft. In view of the penetration of heat, they were constructed with a centre core made of heat-resisting concrete (firebrick and Ciment Fondu).



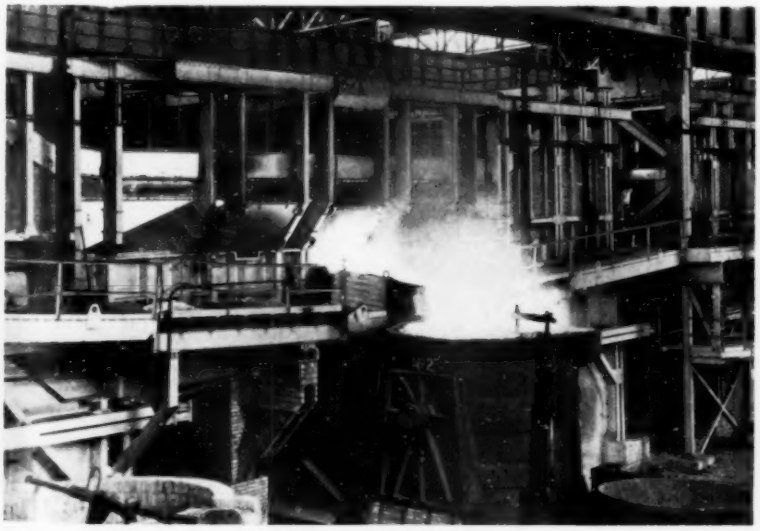
West side of Abbey Works melting shop.

Blast Furnaces.—No. 1 furnace, which has a hearth diameter of 21 ft. 6 in., was "blown-in" in 1946 and has a capacity of 700 tons/day. Originally 16 ft. in diameter, No. 2 furnace was completely dismantled and a new 25 ft. 9 in. furnace which was erected in its place was "blown-in" on November 7th, 1950. The day after No. 2 furnace commenced operation, the dismantling of No. 3 furnace began. Dismantling has now been completed and the foundations have been laid for a furnace similar to No. 2. These two furnaces will each have a capacity of 1,000 tons/day on foreign ore. A new Lodge-Cottrell gas cleaning plant and a further pig-casting plant have also been installed.

Coke Ovens.—In order to provide sufficient coke for the blast furnaces, it has been necessary to build a further 90 coke ovens in addition to the 54 already in operation. These ovens will produce about 15,000 tons/week of coke and will require an input of some 22,000 tons of South Wales coking coal which is brought to the works by rail. On arrival at the works, the wagons are shunted into gravity-operated sidings leading to wagon tipplers which feed the new coal washery by belt conveyor. Further belt conveyors carry the coke from the ovens to the blast furnace bunkers. 60 of the 90 new ovens have been in operation for some five months, and a new by-product recovery plant is also in operation.

Ore Handling.—Home ore from Oxfordshire and limestone from the Company's own quarry at Cornelly is unloaded by wagon tipplers prior to carrying by an overhead conveyor system to the blast furnace bunkers. In order to provide for increased output from Cornelly, the quarry was completely mechanised in 1946.

At the wharf, the unloading of ore from overseas will be facilitated by the three new transporter unloaders which are being installed to replace two unloaders now in operation. One of the new unloaders is in operation while the second is in course of erection. The new unloaders, which are fitted with 12½-ton grabs, will be capable of 500 tons/hr. of ore, compared with 250 tons/hr. with the old ones. The wharf has been extended, and a new concrete structure erected along the whole 1,350 ft. long ore stockyard will carry 100-ton transfer cars to speed up the unloading of the ore.

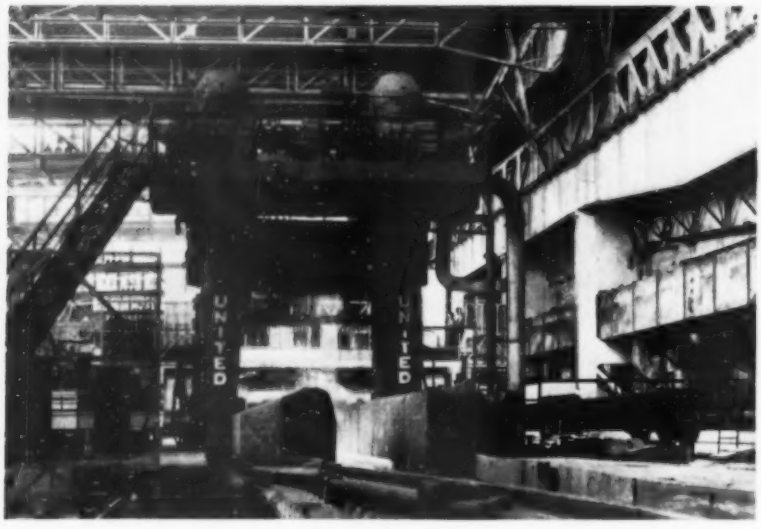


Abbey Works—tapping a 200-ton open hearth furnace.

Melting Shops.—Reconstruction of the open hearth furnaces in the old melting shops at Port Talbot and Margam Works is proceeding steadily. Each shop has six furnaces and so far four at Port Talbot and five at Margam have been rebuilt as 80-ton fixed furnaces.

Abbey Works

Site Preparation.—Extensive civil engineering work was necessary in the preparation of the Abbey Works



Slabbing mill at Abbey Works.

site, the whole 550 acres being raised some 10–12 ft. This operation necessitated the use of 4,500,000 cubic yards of filling, readily available materials being sand from the dunes and slag from old tips and current production. In areas where early construction was not required, sand was deposited by pumping from a dredger craft floating in a lagoon dug in the dunes. The lake formed by the operation of the dredger is now being used as a works reservoir.

In order to prevent inroads by the sea, and to stop sand from blowing in over the works, a sand stabilisation project was carried out over about 83 acres. This work consisted of planting marram grass which, when established, encouraged other vegetation by fixing the sand and preventing drifts. This was later followed by the planting of Corsican and Maritime pine trees. Low-lying areas of the foreshore were brought to a higher level by fixing brushwood hedges against which the sand was blown by the wind until the hedge was buried. Repetition of this process enabled the required height to be reached, when the dune so formed was planted with marram grass, followed by Corsican pine trees.

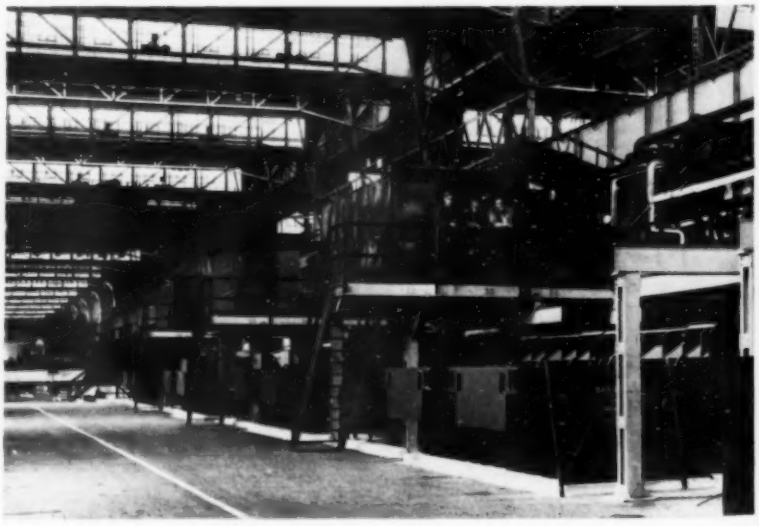
Structural Steelwork.—A weight-saving of 15% in structural steelwork was made by the extensive use of welding. All gantry girders are continuous and these were site-welded at the joints which occurred over each column cap. The gantry rails were welded direct to their supporting girders, a considerable amount of experimental work being carried out before a satisfactory technique was achieved. Throughout the building operations extensive use was made of ultrasonic flaw detection equipment for testing all the important site welds.

A further point of metallurgical interest was the decision to metal-spray all structural steelwork which would be difficult to get at for maintenance painting. Generally speaking this applies to all steelwork above crane girder level and the side sheeting rails. The steelwork was grit-blasted and afterwards sprayed with aluminium to a thickness of 0·004 in. Metal-sprayed steelwork was given one coat of paint while the remaining steelwork was power wire-brushed and given three coats.

Melting Shop.—There will eventually be eight 200-ton fixed oil-fired furnaces in the Abbey Works melting shop; four of these are at present in operation and the remainder in course of construction. Hot metal from the Margam blast furnaces is held in one of two 800-ton mixers which are elevated so that they can pour direct into 75-ton ladles standing on transfer cars at stage level. These transfer cars are hauled to the furnace requiring the iron by electric locomotive.

The bath area of each furnace is 770 sq. ft. and the depth 31 in. Oil for firing is brought by road from the National Oil Refineries in South Wales and pumped into one of two storage tanks, each of 1,000,000 gallon capacity; each charge needs some 5,000 gallons of oil. Scrap is charged into the furnaces by a rail-type charger, after being sorted into qualities in the scrap marshalling yard, pushed up a ramp in trainloads, and loaded into charging boxes in the scrap box filling bay at stage level.

As each 200-ton charge is tapped into one ladle, the combined weight of the full ladle and the ladle crane amounts to something over 700 tons, and to carry this great weight 22 of the largest welded girders ever made have been installed. The longest girders measure 110 ft. × 12 ft. 5 in. × 3 ft. and weigh over 90 tons. For teeming the moulds for the ingots, the largest of which



Slab reheating furnaces at Abbey Works.

will be 20 tons, stand on bogies. A separate building has been erected for the cleaning and preparation of the moulds.

Soaking Pits.—In the ingot stripper bay, to which the moulds are hauled from the melting shop, two 200/40-ton cranes are used for stripping the ingots, which are then charged into the soaking pits for reheating prior to rolling. Of the 20 soaking pits planned, 12 are already in operation. Measuring 15 ft. 3 in. × 14 ft. 3 in. × 11 ft. deep, they are fired by coke oven and blast furnace gas. From the soaking pits, a 100-ton ingot buggy, fitted with a self-operating chair and built-in rollers, delivers the ingot to the ingot-receiving table of the slabbing mill. A novel feature of the plant is the use of "electric eyes" by means of which the buggy automatically stops in front of the soaking pit required.

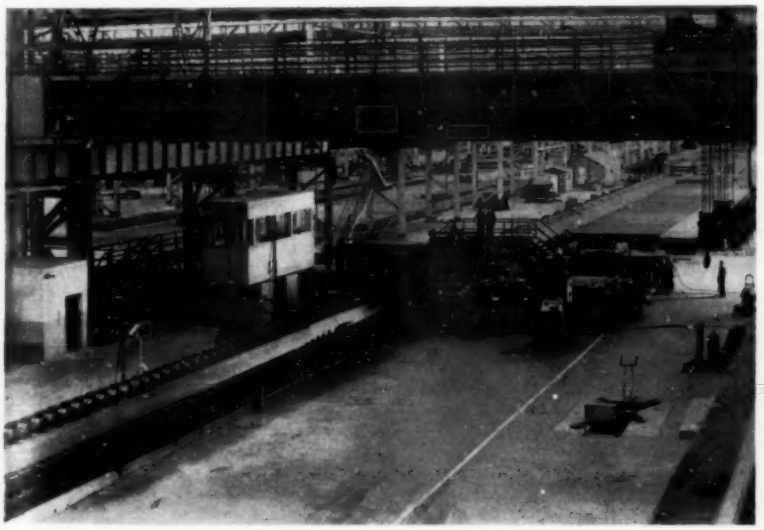
Abbey Works—80-in. continuous mill finishing stands.

Slabbing Mill.—The slabbing mill is a 45-in. mill with 115-in. barrels driven by two 4,600-h.p. motors, power for the motors being supplied by four generators driven by an Ilgner set with a 6,500-h.p. motor. Before passing through the mill the ingot is weighed and turned through 180° so that the wide end of the ingot enters the mill first.

From the slabbing mill, the slab, which may be anything up to 60 in. wide and 8½ in. thick, passes through a separate 800-h.p. A.C. edging mill, 95 ft. beyond the main mill, where the final width is fixed before arriving at the shears. The latter are electrically operated, with a hydraulic balance, and the crops pass by chute to a hoist which delivers them to a separate gantry from which they are taken for scrap.

After weighing, the slabs are carried by conveyor to a high-level table, on which they travel to two pilers which, in turn, pass the slabs to transfer cars for removal to the outer slab yard for cooling and dressing. The dressed slabs are then carried by transfer cars to the inner slab yards for sorting ready to go on two slab furnace depilers.

Reheating Furnaces.—Three reheating furnaces have been installed for reheating the slabs before they enter the continuous mill, and foundations have been made for a fourth furnace to be installed at a later date. Of the triple-zone fired type, the furnaces, which are 93 ft. 9 in. long and 20 ft. 3 in. wide, have a capacity of 105 tons/hr. and can be fired by either oil or gas. Slabs are pushed into the back of the furnace and move on water-cooled skid rails along the whole length, until reaching the discharge door, each slab pushing the preceding one a stage further along the rails. When the furnace is full, the action of charging a fresh slab causes one to be discharged at the front.



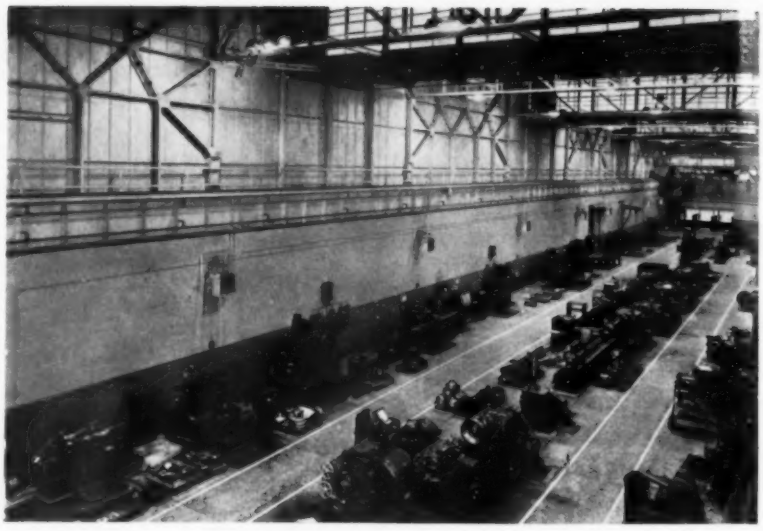
Abbey Works—run-out tables and coilers.

Hot Strip Mill.—On leaving the reheating furnace the slab proceeds via a roller table to the hot strip mill, where it passes first through a scale-breaker for removal of the scale formed on reheating. The slab then enters the first roughing stand which has 54-in. back-up rolls, and 42-in. work rolls with 130-in. barrels. This stand is known as the broadside mill as the slab can be passed through it sideways if it is desired to increase the width up to 72 in. After passing through an edge squeezer, the slab passes through three more roughing stands, each with a built-in edging mill. The back-up rolls of the first two stands are 54 in. with 36-in. work rolls, whilst the figures for the third stand are 54 in. and 27 in., respectively.

Between the last roughing stand and the first finishing stand, there is a delay table, 186 ft. long, to enable the temperature of the metal to be

controlled before entering the finishing mill. The finishing mill, which is preceded by a crop shear, comprises six stands, with pinch rolls feeding into each, and with 54-in. back-up rolls and 27-in. work rolls. Emerging from the last finishing stand at a speed of up to 2,000 ft./min., the strip is carried down by roller table to one of two downcoilers. These are of the collapsing mandrel type and give tight, square-edged coils.

The combined horsepower of the continuous mill is 46,000 and with such high speeds of operation it is obvious that lubrication will play an important part in the efficient working of the plant. The back-up rolls have Morgoil-type bearings, with roller bearings for the work rolls, and a complete circulating oil system for lubrication, together with centralised grease lubrication, are provided. For descaling, a powerful high-pressure water apparatus is in use.



Central repair shop—light machine bay.

On leaving the coilers, the coils are carried on conveyors to the coil-stocking area from which they are being despatched to other works for cold reduction until such time as the cold reduction mills at Margam and Trostre come into operation later in the year. At Margam the strip will be cold rolled on a three-stand mill into wide sheets suitable for motor-car bodies, metal furniture, refrigerators, etc., whilst at Trostre it will pass through a five-stand cold mill before being manufactured into tinplate.

Port Talbot Changes.—A number of changes have been made at Port Talbot works in conjunction with the Margam and Abbey developments. The 32-in. bar mill and sleeper plant remain unchanged, but a new fishplate and soleplate plant, equipped with rotary hearth furnaces has been installed. In view of the ability of the new mill at Abbey Works to roll plates up to $\frac{3}{4}$ in. thick, the plate mills at Port Talbot have been closed down, with the exception of the medium plate mill which will be closed shortly.

Power Plant.—75% of the power requirements of the works are obtained from the British Electrical Authority, the remaining 25% coming from the Company's power station at Margam Works.

A new boilerhouse and pumphouse have been built on to the existing power house and four new boilers, with provision for a fifth in the future, have been installed. They are designed for burning blast furnace gas as the main fuel, with provision for the use of coke oven gas and oil fuel when blast furnace gas is not available. Each boiler is capable of raising 87,500 lb./hour of steam, at a gauge pressure of 625 lb./sq. in. and a temperature of 820° F., for a blast furnace gas consumption of 1,350,000 cu. ft./hr.

Most of the generating and blowing equipment is being replaced by new plant, which will consist of two 8,000-kW turbo-alternators, with provision for a future third set, two auxiliary 1,800-kW turbo-alternators, one turbo-blower of 60,000 cu. ft./min. capacity, two turbo-blowers of 80,000 cu. ft./min. capacity, and one existing turbo-blower of 46,000 cu. ft./min. capacity.

Institution of Works Managers

New Branches

THE Institution of Works Managers has formed three new branches: Northampton, Preston and Wolverhampton. As a result of the formation of the Wolverhampton Branch, the West Midland Branch, out of whose territory the new branch has been carved, has been re-named "Birmingham." The creation of these three new branches brings the number of branches of the Institution to fifteen, twelve of these having been formed in the last four years.

The Institution has throughout adopted a policy of establishing new branches as soon as the number of members has warranted. Thus the former Midland Branch gave birth to the West Midland and Leicester Branches which, in turn, have sponsored the Birmingham and Wolverhampton, and Leicester and Northampton Branches respectively. The new Preston branch has been derived, in part, from members of the Manchester and Merseyside Branches.

All three new branches have resulted from the informal meetings of the few original members in these centres who have gradually drawn other members in and have therefore been granted group, and now branch, status. As a result, members in these centres will be able to enjoy the same privileges of attending lecture-discussion meetings, works visits, and occasional social functions as are enjoyed by members attached to other branches.

The Wolverhampton Metal Co. Ltd.

THE Board of Directors of the Wolverhampton Metal Co. Ltd., recommend a final dividend of 20%, less income tax at 9s. 6d. in the £, payable on September 6th, 1951, to members on the Registers on August 20th, 1951, making 40% for the year ended March 31st, 1951, on the higher capital. This compares with a total for last year of 40% paid on the lower capital (i.e. before the "one for four" Bonus Issue which, in September, 1950, increased the issued capital to £193,311).

Fifty Years of the N.P.L.

Some Aspects of its Work Reviewed

By V. S. Swaminatham

The National Physical Laboratory has now been in existence for 50 years, and in that time has contributed greatly to the advancement of the physical sciences. In this article, the author reviews some of the achievements of the N.P.L. in our field and makes reference to work at present in progress, dealing in this issue with the Metallurgy and Physics Divisions.

THE National Physical Laboratory (N.P.L.) founded in 1900, a year before the U.S. National Bureau of Standards, officially celebrated its Golden Jubilee this year. It furnishes an excellent example of the British aptitude for co-operative research in face of difficulties which are no less insular in their origin and character. Imitation, we are reminded, is the sincerest form of flattery, and Britons would be the first to admit that the N.P.L. is modelled on the Physikalisch-Technische Reichsanstalt at Charlottenburg, Germany. At the 1891 Cardiff meeting of the British Association, Sir Oliver Lodge set the ball rolling by drawing the attention of the audience to the imperative need for an establishment, aiming at the very highest quantitative work in all departments of physical science, which would do for British industry what the Reichsanstalt had accomplished for its German counterpart since the mid-eighties, under the dynamic direction of von Helmholtz. Four years later, the objective was defined as a "National Physical Laboratory" for the more accurate determination of physical constants and for other quantitative research. Reporting in 1898 the Treasury Committee recommended "that a public institution should be founded for standardising and verifying instruments, for testing materials, and for the determination of physical constants," and that it should be established as an extension of the Kew Observatory in the Old Deer Park, Richmond. In giving evidence before this Committee, Sir Douglas Gatton affirmed: "My view is that if Great Britain is to claim its industrial supremacy we must have accurate standards available to our research students and manufacturers," and added, "it is also certain that you cannot separate some research from a Standardising Department." The Treasury Committee's report contained the suggestion that "there are many special and important tests and investigations into the strength and behaviour of materials which might be co-ordinated with great advantage." The Government made an annual grant of £4,000 to the N.P.L. for five years, and another £12,000 for buildings and equipment. It is worthy of note that the German authorities gave an annual grant of nearly £15,000, apart from incurring a capital expenditure of £195,000 on building and equipment, to the Reichsanstalt. The N.P.L. was, until April, 1918, managed by a Committee of the Royal Society, with the addition of representatives of technical institutions and other interests concerned. On January 1, 1900, Dr. (later Sir) Richard Glazebrook took up the appointment of Director of the N.P.L., a post he filled with singular distinction for nearly two decades. He has left on record that the chestnut trees surrounding the Bureau of Standards in Washington, D.C., were grown from chestnuts gathered by George Washington himself from the tree near the gate leading from Bushy House to the Park, believed to have been planted in the time of Charles II.

The N.P.L. now comprises 10* full Divisions, each comparable in scale with the entire original establishment, together with an Electronics Section and a Test House. It has 16 large, and a number of small, buildings on a site of about 50 acres. Until 1918 the Laboratory was controlled by the Royal Society, who appointed a General Board and an Executive Committee to manage its affairs. In April, 1918, it became a part of the newly constituted Department of Scientific and Industrial Research (D.S.I.R.). By agreement with the latter body, the Royal Society continues to control and advise on the work from its scientific aspect, and the President of the Royal Society is *ex-officio* Chairman of the General Board. The Executive Committee consists of representatives of the Royal Society, and of the principal learned societies and professional institutions whose interests lie in the same field as the work of the Laboratory. The present Director is Professor E. C. Bullard, F.R.S. who assumed office on January 1, 1950.

The N.P.L. was set up to carry out research with particular reference to the accurate determination of physical constants; to establish and maintain precise standards of measurement; and to make tests of instruments and materials. It also undertakes investigations of special problems on behalf of Government Departments, for Research Associations representing various industries, and for technical institutions, industrial firms and others, payment being received for the work done for outside bodies. The research work of the Laboratory includes most branches of physics—light, electricity and magnetism, radio communication, engineering, mathematics, metallurgy, aeronautics and ship design in relation to form and propulsion. Results of Laboratory researches are published in the proceedings of scientific societies or in technical journals and in the "Collected Researches" of the Laboratory. An annual report is issued on its work, and a collection of abstracts of all the papers contributed by the Laboratory to the scientific and technical press is published annually. Lists of titles of current papers are issued from the Laboratory monthly, with the object of informing industry of investigations recently completed. In short, the benefits that have accrued from the work of the N.P.L. during its first 50 years of existence have exceeded by far the most sanguine expectations of its promoters.

The Metallurgy Division

Work of interest to industries using metals, alloys, plastics, etc., is carried out in more than one Division.

* When the majority of the work of the Engineering Division has been transferred to the Mechanical Engineering Research Organisation at East Kilbride there will be only nine.

Rolling mill for the production of test material and for studying the effects of rolling on the properties of metals and alloys.

In 1906 the chemical and metallurgical work of the Physics Division was transferred to the new Metallurgy Division of which the late Dr. W. Rosenhain was the first Superintendent. The present Superintendent is Dr. N. P. Allen, and the Division is concerned with methods of analysis, X-ray and electron diffraction studies, the application of the electron microscope to metallurgical work, plastic deformation and creep of metals, the influence of alloying elements in steel and properties of metals and alloys.

The main Metallurgy Building was built largely by the generosity of the late Sir Julius Wernher, but considerable additions have since been made. The primary work of the Division is the investigation of the physical and mechanical properties of metals and alloys, and their constitution and structure—a work with several facets. It includes the systematic examination of alloy systems in which the proportions of the different constituent metals are varied over a wide range. The properties of the resulting materials are studied with a view to determining how the several constituents affect them, and to selecting for further investigation those alloys or groups of alloys in the series which may be most valuable for a variety of practical purposes. The work also embraces investigation of the effects of different heat and mechanical treatments, and of the several processes which must be employed in the application of the materials for constructional purposes. Such methods of investigation range from examination of the structure of the metal or alloy with the microscope, or by means of X-ray or electron diffraction, to mechanical, thermal and electrical tests of the resulting product, in which co-operation of other Divisions of the Laboratory is enlisted. Particular attention is paid to the application of comparatively new tools such as the electron microscope.

For an appreciable period, the Division has been active in the study and development of aluminium and magnesium alloys. Indeed the introduction of alloys of aluminium for aircraft construction some 35 years ago was largely due to the work of the N.P.L. Investigations of the phenomena taking place in them during the age-hardening process have been a noteworthy feature of subsequent work. Of late, work on the constitution and mechanical properties of magnesium alloys has been carried out. The properties of these alloys at ordinary temperatures have received particular attention, and the working and heat-treatment procedures giving the best combination of properties in bar and sheet have been formulated. The design of moulds to give suitable ingots for forging and rolling has also been studied. Magnesium alloys containing cerium and small proportions of other metals have been found to have exceptional properties at elevated temperatures and bid fair to prove of practical importance.

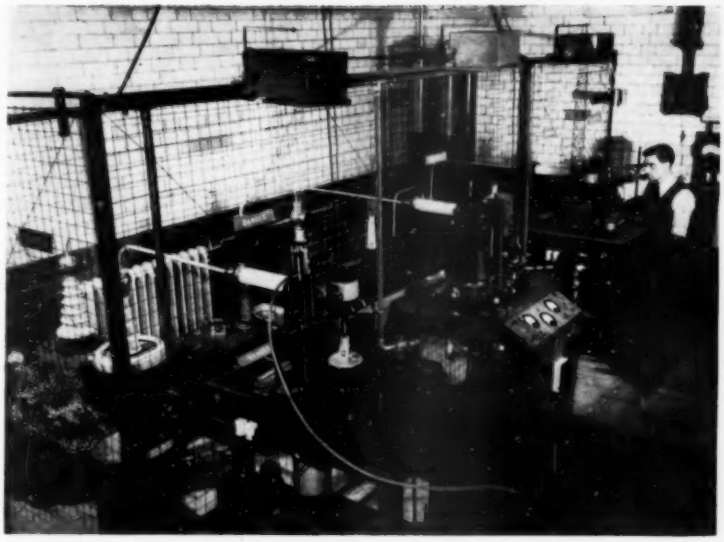
Another aspect of the Division's activity is the preparation of metals, including those of the rare elements, in a high state of purity, for determining the physical properties of the pure metals, and for the study of alloy systems free from impurities. Production of pure iron (99·970%), in ingots of some 25 lb. weight, is now a routine matter. Other very pure metals produced are beryllium, magnesium, chromium, manganese and cobalt, and the effects of addition of certain of these to other metals and alloys have been studied.

The Metallurgy Division has facilities for the production and fabrication of metals on a semi-industrial scale. Thus various processes of casting, press and hammer forging, rolling, etc., are carried out under conditions

25 lb. capacity high-frequency vacuum melting furnace.

permitting of precise control of factors affecting the ultimate product and especially of the temperature and general heat treatment. Furnaces of various types designed and constructed in the Division are installed in the foundry and rolling mills, and electric high-frequency furnaces, including a special valve-controlled high-frequency furnace, have been found helpful for work involving high melting temperatures, such as researches on iron and on materials for use at elevated temperatures.

Researches undertaken by the Division include work on alloys of iron, fundamental investigations into the physical constitution of metals and alloys and the influence of stress on their structure and properties, and investigations of problems connected with the presence of gases and non-metallic inclusions in steel. During the war, a study of the hardening of steels suitable for projectiles and the mechanism of the penetration of armour, occupied a prominent place, while researches on the constitution of weld metal, on the causes of cracking of gas cylinders, and on the properties and defects of sintered tungsten carbide compacts have also been carried out.



X-ray diffraction room showing three X-ray tubes with high-voltage generators behind screens in the background.

The Division has co-operated in the researches on fatigue phenomena, alloys at high temperatures, spring steels, and wrought-iron chains and other lifting tackle. It has also carried out special investigations for the British Non-Ferrous Metals Research Association. On behalf of industry, it has undertaken several special investigations to elucidate and, if possible, find remedies for difficulties encountered in engineering and manufacturing process. In particular, along with the Engineering Division, investigations are made into the cause of failure of structural parts such as boiler plates, connecting rods and other engine components, chains, boiler tubes, turbine blading, etc.

A Chemical Laboratory for carrying out analysis connected with metallurgical work and the work of other departments of the N.P.L. is attached to the Division, and its Refractories Section studies the properties of special refractories for use at elevated temperatures. The experience of this Section has been called on in a variety of problems, such as the production of sintered alumina cutting tools and the development of refractories to withstand load and corrosive attack at high temperatures.

The Division is investigating several reactions involving the high-temperature reduction of pure metallic salts of vanadium and titanium in a specially developed apparatus. These reactions are being examined to determine their practical possibilities and values of the heat changes, rate of extraction and theoretical yield are being determined.

The behaviour of molybdenum steels under steam and stress at high temperatures is being studied in a steam corrosion unit. Tubular specimens are fixed into the apparatus at one end and sealed off by a welded cap at the other. Under a steam pressure of 1,000 lb./sq. in. at 600° C., the specimens are subjected to stresses of from 3 to 9 tons/sq. in. Various materials are being tested in this way, including stainless steels. Laboratory tests reveal that the presence of a surface notch in creep specimens brings about a marked reduction in the "life to rupture" in certain molybdenum steels, whereas other steels of similar composition are not so affected. The original tests were made in air, but similar tests are now under way to ascertain whether failure is accelerated by oxygen-free steam. Investigations of the effect of surface defects in steam mains in power plants indicate that they may lead to the formation of cracks under prolonged loading.

Dilatometric and microscopic phase studies of the iron-nickel and iron-nickel-chromium systems are in progress. The rate of transformation of alpha to gamma on heating binary iron-nickel alloys is measured by the dilatometric method, and investigation has shown that the reaction takes place by two distinct mechanisms, one slow and involving diffusion, and the other rapid and not involving diffusion. The two transformation mechanisms give rise to different microstructures and appear to be analogous to the "diffusion" and "shear" transformations that occur when carbon-containing austenite transforms to alpha on cooling. The free energies of the alpha and gamma solid solutions of iron-nickel alloys have been estimated from the ratios of hydrogen and water vapour in equilibrium with the gamma solid solution at high temperatures, combined with certain data on the heat content of the alloys. From the figures obtained the equilibrium diagram of the system is deduced approximately.

In the ternary iron-nickel-chromium alloys, the limiting compositions at which the sigma phase is first formed have been traced for temperatures of 550°, 650° and 800° C. A characteristic of the alloys is the very sluggish behaviour of alloys containing from 20–30% of nickel. The precipitation of the sigma phase from the gamma solid solution is not always a single stage reaction, but is sometimes preceded by the precipitation of a certain amount of metastable alpha phase which shows marked reluctance to disappear on annealing.

Another recent study of the Division pertains to rapid rolling of magnesium alloys. The effect of the rapidity

Adjusting a microphone in the acoustics laboratory. The heavy triple door effects complete sound insulation between rooms.

of reduction in thickness on the workability and subsequent mechanical properties of high strength magnesium alloys containing aluminium has been extensively examined. By adopting high initial rolling temperatures and rapid rolling, cast slabs of alloys containing up to 7% of aluminium can be reduced from 1·5 to 0·3 in. satisfactorily without reheating. A rapid reduction to 0·1 in. is possible without edge defects becoming serious. The properties of an alloy containing 7% of aluminium in the hot rolled condition are given below :—

0·1% Proof Stress	13–14 tons/sq. in.
Ultimate Tensile Strength	21–22 tons/sq. in.
Elongation per cent. on 2 in. ..	18–20

The Physics Division

Much of the work of the Physics Division, with Dr. B. W. Robinson as Superintendent, is of interest to the metal industry. Its field covers heat, temperature measurement, radiology, sound and ultrasonics. The Heat Section is concerned with researches and routine tests in the thermal properties of materials. Facilities are available for conductivity measurements on building materials, insulants for refrigeration work, refractories for furnace construction, investigations of metals up to temperatures of 1,200° C. or higher, as well as special items such as plastics, ceramics, etc., and for air-to-air heat transfer data for composite panels used in modern building construction. Researches on specific heat include the study of metals up to 1,200° C. as well as of materials like oils, powders, etc.

Apart from routine tests, the Temperature Measurement Section investigates temperature measurement problems in industry such, for example, as the measurement of the temperature of liquid steel, the accurate determination of the temperature of the human body in connection with thermal treatment for special diseases, the rapid control of the temperature of milk in pasteurising plants, and many other cases in which problems of temperature measurement afford features of interest and difficulty. The Radiology Section has instruments specially adapted for measuring low intensities of X-radiation for use in the study of the protection of operators of X-rays in medical and industrial work, whilst the Sound Section deals with various problems in architectural acoustics, the measurement of noise and the testing of instruments. Particular attention is paid to measurement and analysis of noise in industrial operations and much work has been carried out on aircraft noise and problems pertaining to the silencing of aircraft engine test houses.

Recent refinements in the techniques of tracing ultrasonic waves through metal specimens have made possible the precision measurement of the elastic constants, either of small single crystals, or of polycrystalline specimens. In co-operation with Metallurgy and Engineering Divisions, elastic constants are being determined of a series of alloys, e.g., of copper or of aluminium; and the measurements may also give information about grain size and anisotropy.

A large volume of work is carried out by the Physics Division on measurements of heat transmission through materials for building construction, manufacturers submitting a variety of panels representative of new forms of construction to obtain appropriate coefficients of transmission for them. In addition, many materials used for thermal insulation in steam plants and industrial installations are studied. This Division is also investigating the properties of single crystals of gallium, a low melting point metal, whose orthorombic crystalline form makes it an interesting metal in which to study the dependence of conductivity on the crystalline direction.

To be continued

Nickel Production Shows Encouraging Increase

At the Annual Meeting of the International Nickel Company of Canada Limited, last April, Dr. Thompson, Chairman and President of the Company, announced that by the year's end the Company's production of refined nickel would be increased by the amount of 1,000,000 pounds monthly. As a result of intense effort at the Canadian plants in underground mining, metallurgical process changes and emergency facilities, this objective has already been achieved only three months after the statement was made, instead of eight months as conservatively predicted by Dr. Thompson. This encouraging increase brings total production to 21,000,000 pounds per month making it possible for the various world's markets to obtain some additional refined nickel. This production level is again higher than has ever before been achieved in peace time.

Davy and United Engineering Co. Ltd.

At a meeting of the Board of Directors of the Davy and United Engineering Co. Ltd., on July 25th, 1951, it was decided to recommend a dividend on the 941,250 stock units of 10% actual (2/– per stock unit) less income tax at 9s. 6d. in the £ for the year ended 31st March, 1951. Stockholders are to be offered the right to subscribe at par for one new share for every £20 of stock held.

The Engineering, Marine and Welding Exhibition

New Developments on Show at Olympia

A wide range of products will be displayed at the Engineering, Marine and Welding Exhibition, which opens on August 30th and remains open until September 13th. This year the Foundry Trades Exhibition is incorporated, and it is hoped that the brief preview of exhibits presented below will be of value to readers, whether or not they are able to visit the exhibition.

THE Engineering, Marine and Welding Exhibition, which this year incorporates the Foundry Trades Exhibition, will once again be the largest event of its kind in the world. First held in 1906, the exhibition has been held ever since in alternate years, apart from the interruptions caused by the two World Wars. As usual, the venue will be Olympia and the exhibition will be open from 10 a.m. to 8 p.m. each weekday from August 30th to September 13th.

All three halls—the Grand Hall, the Empire Hall and the National Hall—will be in use, and in the description of the exhibits which follows, the location of the stand will be given as follows : The row name or letter, the stand number, and the initial letters of the hall. Unless otherwise stated the stand is on the ground floor. For example P6 NH indicates Stand 6 in Row P on the ground floor of the National Hall, whilst Outer 20 GH Gallery means Stand 20 in the Outer Row of the Grand Hall Gallery.

ENGINEERING AND MARINE SECTION

The products of the engineering industry, with its force of over 2,750,000 men and women, have made a highly significant contribution to increasing the level of production in 1950 in this country by 40% above the 1946 volume. Manufacturers of industrial machinery and equipment have set an example by producing 70% more goods last year than in 1946. Engineering exports, including electrical goods and vehicles, were valued at £808,000,000 in 1950 and reached the highest figure ever recorded in the history of the British engineering industry. On the marine side, the U.K. continues to maintain its leading position in the world to-day for the construction and launching of merchant shipping. In 1950 the tonnage of merchant shipping launched in the U.K. was 1,325,000 tons—over one-third of the world's recorded total and the highest figure for 20 years. The only other country which launched over 10% of the world total was the U.S.A. (437,000 tons).

Wrought Steel and Ferrous Castings

The ferrous exhibits on the stand of *J. Brockhouse & Co., Ltd.* (B13 GH) will include drop forgings (up to 150 lb.), iron castings (up to 2 tons), steel castings (up to 6 tons), acid-resisting castings, cold-rolled sections, railway ironwork and all steel anvils and vices, manufactured by various members of the Brockhouse Organisation.

As specialists in the production of steel castings for steam turbine plant, *The David Brown Foundries Company* (10 NH) will show the bottom half of an H.P. turbine casing weighing some 3 tons. Other examples of foundry capacity will comprise stainless steel castings, high tensile steel castings, centrifugally cast heat-resisting castings for gas turbines, precision castings and a variety of Taurus bronze castings.

Various Meehanite castings will be shown by the *Butterley Co., Ltd.* (P3 NH) along with a section of Butterley iron tri-pedal paving which is widely used for factory floors, whilst the rolling mills where Butterley wrought iron is rolled will be represented pictorially.

Exhibits on *The Chesterfield Tube Co., Ltd.* stand (H6 GH) will be drawn from the wide range of tube products made by the company. These include seamless steel water and steam drums (up to some 3 ft. internal diameter), seamless steel air/hydraulic accumulator bottles, cold-drawn seamless steel H.P. steam pipes, solid-drawn steel headers for boilers, superheaters and economisers, seamless stainless steel tubes, and all kinds of seamless steel cylinders for compressed gases.

The Darlington Forge, Ltd. (J11 GH) has a long-established reputation for marine steel forgings and castings and whilst space will preclude the exhibition of some of the more spectacular products, there will be much of interest to see concerning the firm's specialities which include marine forgings, such as propeller shafting, piston connecting rods, rudder stock, etc., ships' structural steel castings, cast steel back-up rolls, forged die blocks, etc.

An outstanding exhibit by *English Steel Corporation, Ltd.* who share Stand J11, will be an 11 ft. 9 in. diameter machined hollow forged gear wheel rim weighing 7½ tons. Also of interest will be the R.R. continuous grain-flow crankshaft which posseses all the characteristics of a drop forging in sizes beyond the scope of any British drop forge. Other exhibits on view will include a 23 ft. 6 in. propeller shaft with bronze liner, a selection of forging sand a display of tools.

Castings, photographs, test samples and physical property charts illustrating the use of Meehanite Metal in a wide field of casting applications will be seen on the stand of the *International Mechanite Metal Co., Ltd.* (E13 GH). Of the 50 British and European licencees, a large proportion are engaged in the production of diesel engines, turbines, steering gear, pumps, valves, pistons and cylinders, etc., and these are well represented on the stand, whilst in the field of steel replacement, the exhibits include crankshafts, press tool parts, lathe castings, etc.

Manufacturers of all types of steel forgings up to 16 tons in weight, *Mitchell, Shackleton & Co., Ltd.* (Inner 4 NH) are specialists in finished machined crankshafts, of all sizes and designs, for diesel engines, gas engines, com-

pressors, pumps, etc. Crankshafts for eight-cylinder engines are manufactured in one piece, weighing 6–7 tons finished, and measuring 23 ft. long. Repetition machine upset forgings are also manufactured.

Stewarts & Lloyds, Ltd. (7E GH), with associated and subsidiary companies, are exhibiting a selected range of their products on a double-decker stand. Approved for use in both smoke and water tube boilers, S. & L. electrical resistance welded tubes will be shown for the first time. Also featured will be a series of colour transparencies illustrating sequences in the manufacture, protection and laying of large diameter steel mains, together with samples of various types of joints, steel castings and tubular steel structural work.

The essential feature of *The Technically Controlled Castings Group* (J13 GH) is its insistence upon the highest possible standards of quality. Mural displays and exhibitions of radiographs will demonstrate the standards obtained in regular production, as well as the technical controls and inspection procedures which are enforced in the foundries of member-firms of the Group. A representative selection of Teconic castings in steel, grey, high-duty and alloy cast irons and blackheart malleable will complete the exhibit.

The *United Steel Companies* stand (C10 GH) will again provide a communal display on behalf of the various subsidiary and associated companies, which include Steel Peech & Tozer, Appleby-Frodingham Steel Company; Samuel Fox & Co., Ltd., Workington Iron & Steel Company, and United Strip & Bar Mills. The display will illustrate the varied and modern plant in operation at the various works engaged in producing steel in all shapes and sizes in addition to refined irons for foundry purposes. A qualified staff will be constantly in attendance to discuss visitors' problems.

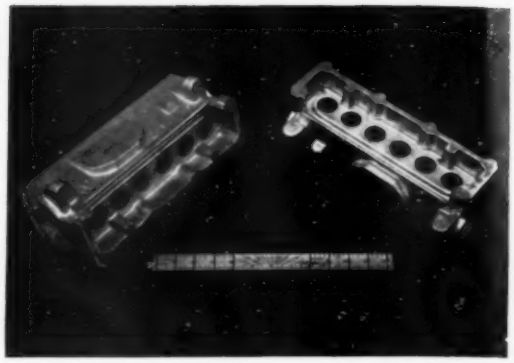
Other ferrous castings will be seen on the stand of *George Cohen & Sons, Ltd.* (L3 GH) where *K. & L. Steelfounders & Engineers, Ltd.* will be exhibiting cast steel anvils and SCOA-P cast steel locomotive wheel centres, and on that of *The Anti-Attrition Metal Co., Ltd.* (Outer 44 GH Gallery).

Non-Ferrous Metals and Castings

A wide range of interest will be covered by the display of *Almin, Ltd.* (R2 NH) which will feature the products of its subsidiary companies *Southern Forge, Ltd.* (aluminium alloy sections, tubes and forgings); *Renfrew Foundries, Ltd.* (aluminium alloy sand and die-castings); and *Structural & Mechanical Development Engineers, Ltd.* (aluminium structures and prefabricated buildings).

The products of *The Anti-Attrition Metal Co., Ltd.* (Outer 44 GH Gallery) of most metallurgical interest are bronzes and white bronzes, ferrous and non-ferrous castings, gravity and pressure die-castings, chill-cast phosphor bronze sticks, lined and unlined bearings, finished machined components, pressings and stampings, and machined bushings, centrifugal castings, etc.

The application of Birmabright aluminium alloys in certain marine spheres is emphasised on the stand of *Birmabright, Ltd.* (H14 GH) and three relatively new developments are illustrated: (a) The lining of holds of refrigerated ships with Birmabright sheet; (b) fish hold linings, stanchions, fish boards and shelves, superstructures, funnels and radar towers for trawlers; and (c) davits for ships' lifeboats. In the construction of the stand a number of examples of argon-arc welding will be incorporated, illustrating the latest development in the welding of thick marine plates. Another feature of the stand will be the use of the new Hob Nail Pattern treadplate for the flooring.



Courtesy of The Non-Ferrous Die Casting Co., Ltd.

Aluminium housing for fuel injection pump manufactured by the low pressure process, incorporating a sand core.

On the stand of *The Eyre Smelting Co., Ltd.* (N9 NH) there will be exhibited a range of non-ferrous metals. These will include Tandem white metals, white metal lined bearings, rope capping metals, mould metals, pattern metals, die-casting metals, Esco gun metal and phosphor bronze ingots, Ariel & Esco chill cast phosphor bronze rods, Eyre brand aluminium alloys, and Bamber's non-encrusting zincs for Leclanche cells. Demonstrations will be given of the tinning of bearings with Fryolux tinning compound and Fryolux tinning paint. A scale model showing a suggested layout for a white metalling plant will also be on view. Other soft-soldering exhibits shown on this stand by *Frys Metal Foundries, Ltd.* will include the various solders and the forms in which they are manufactured, together with a range of suitable fluxes (Frysol soldering fluid, Frysol soldering paste, Alcho-re soldering fluid, etc.) and composite materials (Fryolux solder paint, Fryolux pure tin paint, Alcho-re cored solder wire, Alcho-re solder cream, etc.).

The Glacier Metal Co., Ltd. (Inner 50 GH Gallery) will be exhibiting a comprehensive selection of plain bearings and bearing metals including standard steel backed, white metal lined, thin-wall engine half-bearings, standard steel backed, lead-bronze lined wrapped bushes, standard bronze bushes, and standard bronze bars, all in numerous sizes. There will also be shown standard tin- and lead-base white metals and examples of plain bearings made to customers' specifications.

Aluminium sand castings, aluminium gravity die-castings and sand-castings in bronze, gun metal, brass, etc. will be featured on the stand of *C. & L. Hill, Ltd.* (N7 NH) together with samples of the well-known Hilchil chill-cast phosphor bronze bars.

The exhibits of *The Hoyt Metal Co. of Great Britain, Ltd.* (Outer 32 GH Gallery) will include bearing metals; precision finished bearings (lined and solid) for engines, including copper, lead and aluminium bearings; bronze products—castings, chill-cast and cold-drawn bars and rods, etc.; solders, fluxes and tinning compounds; Kirksite "A" metal for press tools, dies, etc.; and zinc-base pressure die-casting alloys. Also on view will be examples of large bearings white-metalled by the company's own process and designed to ensure the maximum adhesion.

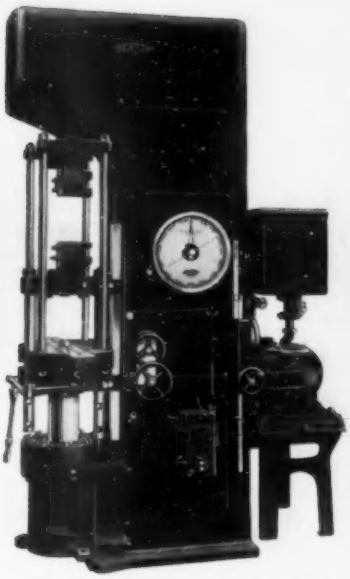
The *Metals Division* of *Imperial Chemical Industries,*

Courtesy of Radio Heaters, Ltd.

Radyne 8/10 output induction heating equipment complete with work table.

Courtesy of Applied High Frequency, Ltd.

25 kW induction heating unit.



Courtesy of Saml. Denison & Son, Ltd.

Model T42A2 self-indicating universal testing machine.

Ltd. (Inner 5 NH Gallery) will be exhibiting condenser tubes in AE cupro-nickel, Alumbro, Admiralty brass and 70/30 brass and special interest will be aroused by the display of Alumbro tubes withdrawn from R.M.S. *Aquitania* after 20 years' perfect service. Other exhibits will include Kunifer tubes for sea-water trunking; Kynal aluminium alloy treadplates; Kuterlon copper tubing for underground water supplies and various pipe fittings; copper and aluminium alloys in various wrought forms; and a number of special-purpose copper alloys for corrosion resistance, high-speed machining, welding tips, and electrical resistance purposes.

For general and marine engineering purposes *Langley Alloy, Ltd.* (H12 GH) will include in their display samples of their Hidurax range of aluminium bronzes in cast and wrought form, and of Hidurit manganese bronzes and nickel silvers. In the electrical industry, the Hidurel series of high conductivity alloys find wide application in switchgear, resistance welding, etc. There will also be shown nickel alloys and stainless steels of special interest in the chemical and process field. The display will include castings in Monel, nickel, Inconel, the Langalloy R series of special nickel alloys, and in the Langalloy 1V and 3V grades of stainless steel.

The theme of *The Mond Nickel Co., Ltd.* stand (G2 GH), which is shared with *Henry Wiggin & Co., Ltd.*, will be the history of nickel since its discovery by the Swedish scientist Cronstedt 200 years ago. The individual exhibits will include a model of Cronstedt's laboratory; copies of classic papers in the history of nickel, shown against a background of uses and including the first description of the art of nickel plating, the first patents on nickel-chromium and nickel-chromium-iron alloys, original papers on malleable nickel and low-expansion iron nickel alloys, and material relating to the introduction of the nickel copper alloys. Examples of nickel and its alloys will be shown and there will be a full range of technical publications available.

On the stand of *The Non-Ferrous Die Casting Co., Ltd.* (F1 GH) gravity castings in brass and bronze to various specifications and in a range of sizes will be exhibited. An outstanding feature is the superior general finish which has recently been further improved by developments in die dressings. Aluminium castings made by both gravity and low-pressure processes will be shown and the excellent definition and smooth surface will be noted on the castings made by the low-pressure process which also results in even grain structure and reduced porosity.

A select range of aluminium extrusions, strip, sheet, etc., suitable for use in marine and general engineering, and complying with Lloyds and other appropriate regulations, will be displayed by *T.I. Aluminium, Ltd.* (Inner Gallery 8 NH).

Die-castings in light alloys, made by both the pressure and the gravity processes, will also be seen on the *Brockhouse Organisation* stand (B13 GH).

Tubes in copper-base alloys will predominate in the display on the stand of *The Yorkshire Copper Works, Ltd.* (F6 GH), specialists in the manufacture of solid-drawn tubes in brass, copper, Yorcalbro (aluminium-brass), cupro-nickel, Yorcoron, Yorcabric, Yorcunife (copper-nickel-iron) and other special non-ferrous alloys, and Yorkshire fittings.

Heating Equipment and Temperature Measurement

On the stand of *Applied High Frequency, Ltd.* (P4 NH) there will be found a range of high-frequency induction heating equipments, with outputs of 1, 7·5 and 25 kW and suitable for various soldering, brazing, local hardening and annealing applications. These units can be easily and speedily set up for any job, as the inductance control can be adjusted quickly to match the selected work coil to the generator. There will also be samples of various articles which have been processed and photographs illustrating both the equipment and their many applications.

The English Electric Co., Ltd. (R3 NH) will include in their display of electrical equipment a 25 kW induction heater which is intermediate in the range made by the Company. It embodies the usual features associated

with English Electric radio-frequency heating equipment, giving accurate control, comprehensive set-up facilities and controllable power output.

On *The Incandescent Group* stand (S2 NH) some interesting scale models and photographs representing products and activities of the constituent companies will be found. These companies include *The Incandescent Heat Co., Ltd.; Controlled Heat & Air, Ltd.; Metalectric Furnaces, Ltd.; Metal Porcelains, Ltd.;* and *Selas Gas & Engineering Co., Ltd.*, and their products cover gas-fired and electric furnaces for metallurgical work, foundry equipment, galvanising and enamelling plant, ovens, spray booths, direct-arc steel melting furnaces, induction heating equipment, dielectric core-drying plant, vitreous enamelling materials and equipment, and industrial heating equipment.

Radio Heaters, Ltd. (AA3 EH First Floor) will be showing a comprehensive range of high-frequency induction heating generators, all in operation. The exhibits will comprise the Radyne 1kW, 3½kW, 9kW and 25/30 kW generators, the 3½ kW and 25/30 kW units being on show for the first time. A new comprehensive booklet giving a wealth of valuable information on the applications of high-frequency induction heating, together with full details of the various Radyne equipments, will also be available on the stand. Demonstrations given will include through-heating of bars for forging and upsetting, brazing of carbide tool tips, automatic hardening of small pawls, etc.

On the *British Rototherm Co., Ltd.'s* stand (Inner 18 GH Gallery) there will be exhibited a comprehensive range of bi-metallic and distance reading dial type thermometers for industrial and domestic use, together with mercury-in-steel temperature controllers and recorders and a thermostatically controlled low temperature test tank.

Electrical Equipment

British Insulated Callenders Cables, Ltd. (E14 GH) will present a display of electrical products including ship wiring cables, silicone rubber insulated cables and flexibles, welding flexibles, copper busbars and supporting cleats, and a wire-rope parting machine. The last-named exhibit will be seen in operation and it will be seen that the rope ends are left sealed and in tapered form. The operation can be carried out ten times as quickly as by former methods.

The marine exhibits on the *British Thomson-Houston* stand (N5 NH) will indicate the varied products for use in this field. On the industrial side there will be a display of various types of electric motors, including a new range of totally enclosed fan-cooled machines with standardised dimensions; electric control gear; thrustors; and suds pumps. There will be demonstrations of "Stacreep" (patented) A.C. crane control, and "Clearcall" industrial communication equipment. Mazda lamps and lighting equipment in wide variety for marine and industrial use will form another particularly attractive feature.

An improved type of Young heavy-duty armoured marine battery will be shown by *Crompton-Parkinson, Ltd.* (C9 GH), in which a resin-bonded glass-silk porous envelope encloses the positive plate assembly to hold the active material firmly under conditions of severe vibration and heavy discharge. Electric motors, electrical measuring instruments, and electric cables of all types will also be on view, and a further feature of the stand will be a display of the latest developments in fluorescent lighting.

Reference has already been made to the 25kW high-frequency heater to be seen on the *English Electric* stand (R3 NH). Other electrical exhibits comprise a selection of motors and examples of fusegear. The motors will include A.C. totally enclosed fan-cooled machines for industrial applications from 1 to 20 h.p. inclusive; typical D.C. machines of the ventilated and totally enclosed types for marine work; and A.C. totally enclosed short-time rated crane motors. F.H.P. motors from ⅛ to 1 h.p. will also be on view.

The EM4 55 kV electron microscope shown by *The Metropolitan-Vickers Electrical Co., Ltd.* (J6 GH) has been designed as an inexpensive instrument for routine work in factory or laboratory; it will provide magnifications up to 12,000 with a resolution better than 100 angstroms. Of particular interest, too, will be the Type S crack detector, of the universal type with continuous control of both magnetising circuits. Other exhibits will include models of various projects engineered by the Company.

Oils

The stand of the *Esso Petroleum Co., Ltd.* (O3 NH) will be illustrating various applications of Esso products, samples of which will also be on view, together with photographs and a description of the growth of Europe's largest oil refinery at Fawley. Technical engineers will be in attendance to discuss fuel and lubricating problems and advise on the most recent developments.

The exhibits of *Fletcher-Miller, Ltd.* (AA6 EH First Floor) will include a wide range of cutting and grinding fluids; machine tool lubricants graded for varying conditions of work and mechanisms; industrial lubricants; alkaline degreasing compounds and cold water cleaners; rust and scale removers, rust preventatives and dewatering fluids; drawing compounds; easing oil; quenching and tempering oils; and case-hardening compounds.

A range of lubricants for industrial and marine duty will be displayed by *Germ Lubricants, Ltd.* (M4 NH) including types suitable for diesel engines, steam engines, turbines, and engines suited by HD oils. For machining and working of metals there will be cutting fluids and drawing lubricants. Hydraulic oils will also be exhibited.

An interesting exhibit on the *Shell-Mex and B.P.* stand (F10 GH) will be an experimental test rig as used in experiments to determine the effects of various fuels on gas turbine blades. Demonstrations and talks will be given at intervals, on a subject which is vitally important, as the success of the gas turbine as an industrial prime mover must depend on its ability to burn the cheapest grades of heavy fuel oil.

On the *Sternol* stand (Inner 45 GH Gallery) a full range of inspection samples will be available, including lubricating oils and greases, cutting oils, rust preventatives, and anti-dermatitis preparations. For those interested in foundries there will be a display of core binders in powder, cream, semi-solid and oil form.

Edgar Vaughan & Co., Ltd. (Inner 20 GH Gallery) will exhibit a wide range of cutting oils, drawing compounds, grinding and broaching oils, specialised lubricants, hydraulic oils, rust preventatives, industrial cleaning compounds. Oils, salts and solid carburisers for metal heat-treatment and mechanical leathers will also be featured. Details will be available of the new oil fuel additive, Houghto-Solv "W," and its efficiency will be demonstrated.

C. C. Wakefield & Co., Ltd. (Inner 10 GH Gallery) supply high quality lubricating oils and greases for all industrial and marine applications as well as lubricators and lubricating appliances of every type. Experts on the stand will be able to give visitors guidance on the correct choice and application of lubricants to their own particular problems.

Machine Tools and Factory Equipment

A number of items of metal-working equipment will be on view on various stands: that on the stand of *The Butterley Co., Ltd.* (P3 NH) will be an ungeared, inclinable, open-fronted press. It is designed to give 40 tons pressure near the bottom of the stroke and is ideal for all types of light single action and combination die-work. Typical of the range of overhead travelling cranes, a 5-ton crab for a magnet crane will also be on view.

Among the principal exhibits of *Crofts (Engineers), Ltd.* (CC2 EH First Floor) will be the Ritespeed geared motors and reduction gears, split taper bushed V-pulleys, and the patent BOM-L clutch, of great interest to machine tool makers. A special display which will attract much attention from clutch users will be a working arrangement of mechanical clutches, with emphasis on the Airflex clutch. A fine example of Croft's facilities for fabricated steel constructional work will also be on view.

Further sheet metal working machines will be shown on the stand of *George Cohen, Sons & Co., Ltd.* (L3 GH). They will include the gang slitting shears, a combination punching, shearing, cropping and notching machine, guillotine shears, a press brake, a cramp folder, a high-lift folder, and an undercrank power guillotine, whilst cast steel anvils and mobile cranes will be shown by *K. & L. Steelfounders & Engineers, Ltd.* (C3 GH) an associated company.

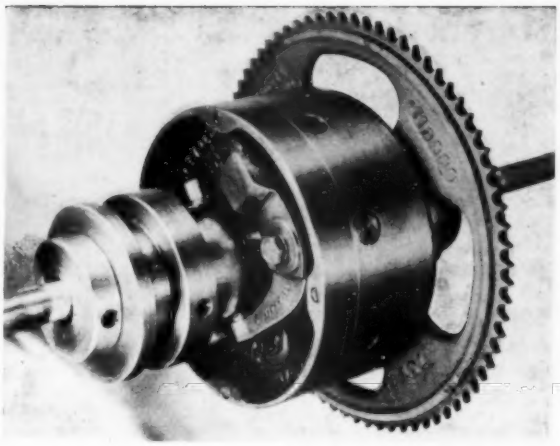
The exhibits of *F. J. Edwards, Ltd.* (E2 GH) will also be mainly in this field and will include several Besco Production machine tools. Of special interest will be the following: a geared guillotine shear, a high-speed nibbling machine, an inclinable power press, a fabricated steel hand punch, a punching, shearing, section cropping and notching machine, a bar cropping machine, and a treadle guillotine.

Hilmor, Ltd. (K11 and 12 GH) will be exhibiting more than 20 models which are representative of the very large range of tube-bending machinery they manufacture. Included in the display will be lightweight benders, hand-operated general purpose machines, portable hydraulic benders, and hand- and power-operated short radius mandrel benders.

The *Keith Blackman* (P8 NH) exhibits are, as usual, concerned with moving air, and will comprise a range of electrically driven fans and blowers, an air-conditioning unit and a dust exhausting and collecting unit. The 30-in. man-cooling fan is used for combating hot spots in iron and steel works, foundries, boilerhouses, etc.

Miscellaneous

The testing machines exhibited by *W. & T. Avery & Co., Ltd.* (H3 and 5 GH) comprise a number of new machines developed in the post-war years and include a 15-ton self-indicating tensile and compression testing machine, and a 150-ton compression testing machine with transverse bending attachment. Two of the new range of electro-dynamic balancing machines will be shown, whilst hardness testing will be covered by Rockwell & Brinell machines, and fatigue testing by a reverse plane bend machine.



Courtesy of The Renold & Coventry Chain Co., Ltd.

Newly designed Renold chain clutch.

Bound Brook Bearings (G.B.), Ltd. (Outer 17 NH Gallery) will include in their display Compo oil-retaining, porous bronze bushes, bearings and parts; Powdiron structural parts; oil-retaining bushings, bearings and parts; Ferrocite oil-retaining iron valve guides; and graphited bronze bearings.

Reference has already been made to the foundry exhibits of the *David Brown Group* (10 NH). On the same stand there will be an interesting display of gear units which will include a 17-in. turbine reducing gear unit with teeth finished by shaving, and a range of gears from *The Keighley Gear Company* and *The Coventry Gear Company*, subsidiaries of David Brown.

One of the main exhibits on the stand of *Saml. Denison & Son, Ltd.* (K15 GH) will be a 15-ton Model T42A2 self-indicating universal testing machine. This is a four-range machine and an interesting feature of the dial is that only the figures appropriate to the range in use are visible. Other exhibits will include universal testing machines of different capacities, a compression testing machine and a creep testing machine.

Exhibits by Research Associations and by Research Stations of the Department will be featured on the stand of the *Department of Scientific and Industrial Research* (Outer 35 GH Gallery). Many of these will have a metallurgical interest as, for instance, the N.P.L. exhibit illustrating work on the study of the creep-resisting magnesium-cerium alloys; a fatigue testing machine for direct stress at 3,000 c/m., a new machine for testing reciprocating bearings, and a demonstration with lead and plasticine models of the plastic deformation of metals, all displayed by M.E.R.O.; exhibits illustrating the work of the B.N.F.M.R.A. on means of economising in scarce non-ferrous metals, together with equipment for detecting gas in alloys, and a rotating-load high-temperature fatigue machine.

Demonstrated for the first time on the stand of *The Metallizing Equipment Co., Ltd.* will be two new metal spraying guns. The Type 4E is primarily intended for the rapid reclamation of worn or mis-machined parts, while the Type 5E has been specially produced for high-speed spraying of anti-corrosive coatings. Both have a syphon-jet to balance the gases, a lightweight aluminium gas-head, a built-in oil pump, and a Metro automatic wire speed governor.

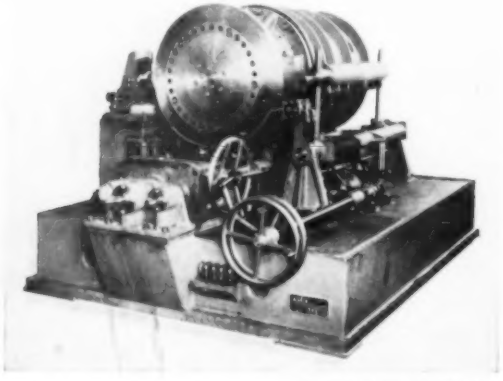
Courtesy of Arc Manufacturing Co., Ltd.

Actarc inert gas welding plant.

The Metalock process of cold repair to iron castings is being widely used throughout the world. On the *Metalock* stand (Outer 52 GH Gallery) there will be on view a few machines which have been repaired by the Metalock process, together with photographs of repairs which have been carried out in many countries.

In the construction of the new *Ark Royal*, Newton Victor industrial X-ray equipment played an important role, and apparatus of the type used by the Admiralty for radiography of the welded structures supporting the immense flight-deck of the vessel will be on the *Newton Victor* stand (M9 NH). This equipment—the "Raymax 250" unit—is a 250 kV set, in which special features are incorporated, suitable for the examination of castings, welded joints and other fabrications up to a thickness corresponding to 3 in. of steel. It will be shown as a mobile, jib-crane-mounted, unit. Also on show will be the "Raymax 140" industrial X-ray equipment.

The exhibits of *The Renold & Coventry Chain Co., Ltd.* (H9 GH) will include a multi-point running display of Renold roller chains and wheels exemplifying the adaptability of chain driving. The variety of size and type of chain exhibited will provide an interesting demonstration of the wide range available. Transmission accessories on view will include chain and flexible couplings and the newly designed Renold chain clutch.



Courtesy of Asea Electric, Ltd.

Tube mill welding head.

As manufactuers of seamless cold-drawn tubes and tubular forgings, the products of *Tubes, Ltd.* (A10 GH) are in the nature of components for other manufacturers. The exhibits will include boiler tubes with a variety of manipulated ends, precision tubes, and tubular forgings for the automobile and other industries.

The Walterisation Co., Ltd. (Outer 22 GH Gallery) are specialists in rust-proofing and metal finishing processes, and the exhibits will include products showing the value of Walterisation in rust prevention and a colour film will illustrate the processes in practice. Foscoto (R.S.) for destroying rust, and Deran for dissolving rust, will be shown, and demonstrations of the former, which is a brush-on preparation, will be given.

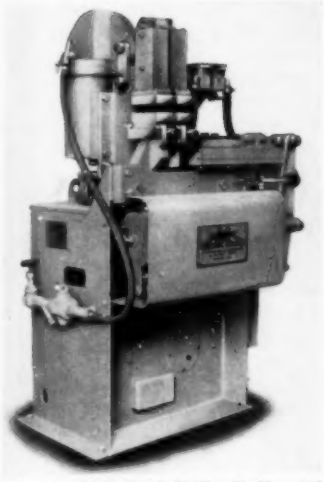
THE WELDING SECTION

A special section of the exhibition will feature a display of welding equipment, and the visitor will be able to see demonstrations ranging from submerged arc welding of steel plate to argon arc welding of alloys of aluminium, magnesium and copper, together with stainless steel and heat-resisting nickel alloys. Special arrangements have been made for the publication during the exhibition of the Report of the Welding Productivity Team which visited the U.S.A. last autumn, and the Team will also be holding a meeting at Olympia whilst the exhibition is open.

Although some of their latest flash-butt welding machines will be shown by *A.I. Electric Welding Machines Ltd.* (V9 EH), the main theme of the display will be the application side of flash-butt welding. Display panels covering a variety of industries will show how various assembly operations are planned for flash-butt welding, resulting in high-speed production at minimum cost. In addition there will be actual examples with production cost figures resulting from simplified forging design and weight reduction achieved by prepared planning for flash-butt welding. Machines for demonstration together with facilities for tests on welded specimens will be available for interested visitors, and examples of flash-butt welded alloy steels and aluminium alloys will be displayed.

The welding equipment shown by the *Arc Manufacturing Co., Ltd.* (V11 EH) will include a full range of welding transformers from 200 to 600 amp. of which the new Media (65 and 95 volt ranges with a current maximum of 300 amp.) will be of special interest; inert gas welding plant on which demonstrations will be given; and a new twin-cylinder air-cooled diesel engine welding set for site work which is very economical in running costs. Of special interest in the display of electrodes will be the "Velvarc," an all-position mild steel rod, giving fast deposition and easy deslagging which may also be used as a touch rod; the "Tetrarc" rod for pipeline welding; and the "Tensarc," a low hydrogen type of rod for medium-carbon and low-alloy steels.

The display of *ASEA Electric, Ltd.* (V14 EH) will include a welding machine for a tube mill, consisting of a rotating transformer with welding electrodes and electrical control gear; an automatic resistance heating and upsetting machine which heats and partially upsets blanks prior to forging or heading; and a new fully automatic arc welding machine which uses standard electrodes and is especially suitable for outdoor use as in shipyards. The welding head of the tube mill will rotate

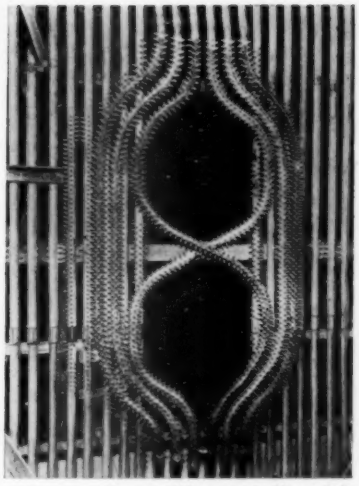


Courtesy of A.I. Electric Welding Machines, Ltd.

Type AF1 automatic flash-butt welder.

Courtesy of Deloro Stellite, Ltd.

Depositing Stellite by arc-welding.



Courtesy of Crompton-Parkinson, Ltd.

Plain studs end-welded on to superheater tubes to increase heat transfer.

to demonstrate its operation and the resistance heater will be fully operated to heat bolt blanks. Various films, including one of the automatic arc welder, will be shown, and there will be interesting examples of resistance welding, arc welding and carbon arc welding of light gauge materials.

The exhibit on the stand of *British Cutting Gases, Ltd. and Associated Companies* (V5 EH) will be planned to demonstrate the unique characteristics of Pyrogas and Super-Pyrogas as an ideal fuel for burning and heating metals and all heating problems common to the commercial and industrial fields of engineering. There will be a display of welding and cutting equipment, and regular demonstrations will be given of underwater cutting.

Blowpipes for welding, cutting, brazing, heating, soldering and paint burning will be featured by *British Industrial Gases, Ltd.* (V12 EH) together with an oxy-fuel gas profile cutting machine. Pressure-reducing precision regulators will also be displayed, together with a wide range of general welding accessories, including wires, rods, fluxes, hoses, goggles, etc. Demonstrations of welding and cutting will be staged from time to time.

Demonstrations of equipment for oxy-acetylene welding and cutting and for argon-arc welding will be featured in the *British Oxygen Company's* display (W7 EH). The complete range of Cutogen hand-cutters will include two noteworthy new models. No. 3 is designed for cutting thick sections of steel and cast iron, whilst No. 5, suitable for the majority of manual operations, can also be supplied with nozzles for gouging, rivet washing, etc. The cutting machines on show will include the latest P.E.P. (plate-edge preparation) machine fitted with the Multi-float attachment. A wide range of accessories will round off the oxy-acetylene display. Argon-arc equipment will include the Mark III water-cooled torch and the A.W.M.3 automatic argon-arc machine.

The welding exhibits of *The British Thomson-Houston Co., Ltd.* (V15 EH) will consist mainly of control panels for spot and seam welding machines. They will include a selection from the extensive BTH range of synchronous control panels and comprise an ignitron contactor unit utilising two BK24/5552 ignitrons with a maximum rating of 1,200 kVA; an ignitron panel for the control of welds up to half-cycle duration; and a synchronous panel using thyratrons, instead of ignitrons, for welding machines up to 10 kVA. In addition there will be interesting demonstrations of the BTH halogen vapour leak detector, which is invaluable for testing welded tanks, pipes, etc.

Possibly the item of outstanding interest in the electrode display on the stand of *Cooper & Turner, Ltd.* (W2 EH) will be a demonstration of the unusually high degree of resistance to moisture offered by the Ruby mild steel electrode, a point of considerable interest for site work, where storage conditions are usually bad. Tests are in hand on a new type of pack which is expected to maintain even those electrodes normally affected by damp in factory-fresh condition, and it is hoped that the results will be available by the time of the exhibition. Among the welding plant displayed will be the latest mobile diesel driven generator incorporating a new type of idling control which results in considerable fuel saving by ensuring that the engine runs at idling speed at all times when welding is not in progress.

Nelson stud welding will be shown on the *Crompton-Parkinson, Ltd.* stand (C9GH). Carried out with a "gun" so simple that all the operator has to do is load it with a stud, place it in position and press a button, the method is 14 times as fast as drilling and tapping. The equipment is operated from a 60–90 volt D.C. supply from (1) the new C.P. metal rectifier unit, (2) heavy duty batteries, or (3) an arc welding motor generator.

Stud welding equipment will also be featured by *Cyc-Arc, Ltd.* (V10 EH) and will comprise the Type E1 controller unit, the Type D portable handtool, and the Type FM machine tool. The last-named incorporates the Type F electro-hydraulic welding head, and welding current for demonstrations will be available from a Cyc-Arc transformer-rectifier unit which may also be used for arc-welding.

Deloro Stellite, Ltd. (W4 EH) will be showing a range of tipped and solid tools, examples of "Stellite" faced work and "Stellite" precision castings such as turbine-blade erosion shields and diffuser blades. A feature of the stand will be frequent demonstrations of "Stellite" facing of production components by the oxy-acetylene

Courtesy of Kelvin & Hughes, Ltd.

Application of supersonic flaw detection to a welded pressure vessel.

method, and anyone interested can have small parts faced with "Stellite" without charge. Examples will be available of arc-welded "Stellite" faced components. Further demonstrations will be given showing how "Stellite" drills operate on hardened steel components. A technical staff will be maintained to answer queries about any of the large number of applications of "Stellite."

Automatic arc-welding plant and continuous electrodes will be featured on the stand of *Fusarc, Ltd.* (V20 EH) together with welding manipulators and jigs for automatic welding. The display will include several model equipments, standard machines and a variety of photographs of applications, together with examples of work carried out by the process. A Fusarc automatic arc deck welder will be on view, showing the general construction and principles of operation, and can be demonstrated to those interested. Qualified engineers will be in attendance to discuss any problems arising from the use of the process.

Of outstanding interest on the stand of *The General Electric Co., Ltd.* (V6 EH) will be the portable twin-arc equipment which represents an outstanding advance in A.C. welding plant. By using an arrangement of two parallel electrodes insulated by their normal flux coating, and fed from a three-phase to two-phase transformer, the whole of the arc energy is concentrated into successively burning arcs from each electrode tip to the work piece. Only a very small (single-phase) component of the current bridges the gap between the electrode tips. A balanced load is taken from the three-phase supply and the set operates at a much higher power factor than the usual single-phase equipment. Other advantages include increased welding speed, ease of operation, less frequent rod-changing, elimination of shock risk, and a cool electrode holder. The set is designed so that it can also be used as a double operator set.

Although the latest longitudinal profiling machine, which can deal with the largest plates used in shipyards, is too large to be shown on the stand of *Hancock & Co. (Engineers), Ltd.* (W9EH) it will be represented by a model and photographs. The wide range of oxgyen-cutting machines on view will feature prominently an entirely new profiling machine of the dual-carriage type, with the burner adjustable over the full width of the machine. It can be fitted with all the standard drives (including electronic) and additional burners for multiple cutting.

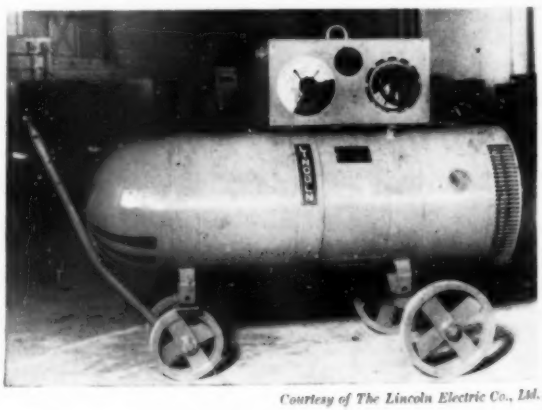
Working demonstrations will be given by *Holden & Hunt, Ltd.* (V1 EH) on a range of electrical resistance welding and heating machines. These will include manually operated spot welders ranging from 5 kVA up to 25 kVA; a motor-driven spot welder; semi-automatic wire butt-welding machines ranging from 3 kVA up to 15 kVA capacity; and rivet heating machines.

Although not situated in the Welding Section, the stand of the *Owen Organisation* (N7 NH) will feature a display of Invicta arc-welding electrodes and welding accessories, together with photographs and examples of welded constructions carried out with Invicta rods.

Two interesting developments being shown by *Kelvin & Hughes, Ltd.* (X1 EH) will be of special interest to the welding industry and users of welded equipment. A photographic mural will depict the application of supersonic flaw detection to the testing of welds in pressure vessels and a team of experts will be available to discuss and demonstrate the use of the equipment in weld quality testing. The method is applicable to butt (including flash-butt), lap and fillet welds and the degree of penetration can be determined as well as the presence of cracks, slag inclusions and porosity. For resistance welding investigations, the high-speed pen recorder, on which volts, amperes, force acting on the electrodes, and duration of the welding operation can be simultaneously recorded, will be shown.

A comprehensive range of arc-welding equipment and accessories will be on view on the *Lincoln Electric Co., Ltd.* stand (U5 EH). There will be included several recent developments, including Lincoln's new electrodes Multiweld and Positionweld which will have a special display. The electrode, Fleetweld 5, will also have a special position; this rod is widely used on pipeline and oil refinery work. The Lincoln machines on show will be the SA 150 motor generator, SA 150 generator, SA 200 petrol welder, SAE 300 petrol welder, and fully and semi-automatic submerged-arc-welding equipment, which will be demonstrated by Lincoln field engineers.

Emphasis will be placed on A.C. and D.C. arc-welding equipment on the *Max Arc & Electrics, Ltd.* stand (W11 EH). The range displayed will include the Max-Arclette A.C. set providing 15–150 amperes with 24 settings; the "250" air-cooled and "300" oil-cooled models, incorporating moving-core stepless control; and D.C. motor generator sets. Special lightweight petrol and diesel



Courtesy of The Lincoln Electric Co., Ltd.

S.A.E. 600 motor generator.

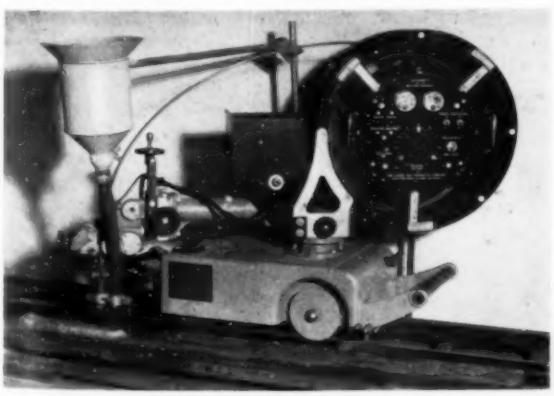
engine-driven sets will also be on view; a particularly popular unit among agricultural engineers provides 4,000 watts at 230 volts A.C. for power tool drive or lighting and incorporates 15–170 amp. for arc welding.

The electronic control of weld metal deposition will be demonstrated by the automatic arc-welding machine on the stand of *The Metropolitan-Vickers Electrical Co., Ltd.* (V8 EH), which will show the high welding speed possible. Included in the equipment on show will be the Thermac transformer set, the Paradyne D.C. set, and an atomic-hydrogen set for light-gauge welding and hard surfacing. In the resistance welding field, two air-operated spot welders, one with the covers removed, will show the robust design and pleasing appearance, whilst the light-weight portable spot-welding gun will be of interest to many. Samples of the M-V electrodes and accessories will round off the display.

Many new exhibits of outstanding interest are being shown on the stand of *Murex Welding Processes, Ltd.* (W5 EH). These include a new 50-amp. transformer welding equipment, a newly designed 250-amp. transformer equipment, a recently developed low voltage device for A.C. welding equipment, the Elin-Murex automatic welding equipment, and some new types of electric arc-welding electrodes. Among the other types of Murex electric arc-welding equipment being shown are some engine-driven sets which have been specially prepared with cut-away sections to show the internal components. The exhibit is completed by a display of Murex arc-welding electrodes, the range of which now covers over 70 different types, and displays of arc-welding accessories and Murex welding literature. Practical demonstrations in both manual and automatic arc welding are being given.

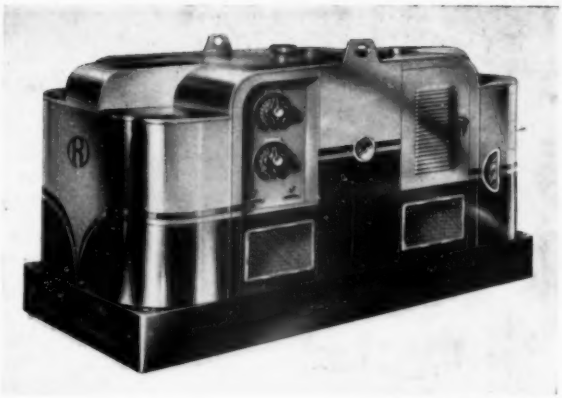
A comprehensive range of Lion electrodes for numerous ferrous and non-ferrous applications will be shown by *G. D. Peters & Co., Ltd.* (W3 EH), together with operators' accessories such as electrode holders, shields, hammers, cable, aprons, etc. D.C. welding plant will be represented by a Model 257 "LD" single-operator portable diesel-engine-driven set, whilst the A.C. welding equipment exhibit will consist of a single-operator portable oil-cooled set which is completely self-contained, the transformer and regulator being mounted together in one tank.

The exhibits on the main *Quasi-Arc* stand (W8 EH) will include transformer and motor generator welding sets together with a DE.300 diesel-engine-driven mobile welding unit as used on the Finnart Pipeline in Scotland, and a PE.250 petrol-engine-driven set which can be split into two units to permit manhandling on site. The PE.250 also incorporates a remote current control attachment. There will be continuous demonstrations of up-to-date welding technique, including the use of the recently developed rods for welding pipe butt joints in situ, and for flat welding of work subject to radiographic examination. The range of Quasi-Arc electrodes and welders accessories will be on view, whilst the new Q.A. sound and colour film will be shown continuously.



Courtesy of The Quasi-Arc, Co., Ltd.

D.S. Unionmelt head up to 1,200 amps. capacity.



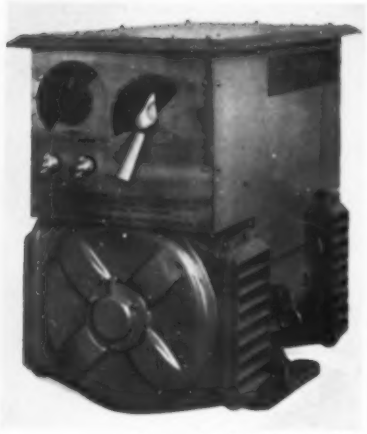
Courtesy of Rockweld, Ltd

New engine-driven welding set with Armstrong air-cooled engine and stepless current and voltage regulation.

On the *Unionmelt Automatic Arc Welding* stand (W10 EH) Quasi-Arc will be demonstrating the complete range of modern Unionmelt submerged arc automatic welding equipment, including models not yet in general use in this country. Fully automatic equipment will be in operation with both electronic and series controls, as well as Unionmelt machines for manual and semi-automatic welding for operation from A.C. or D.C. power pack.

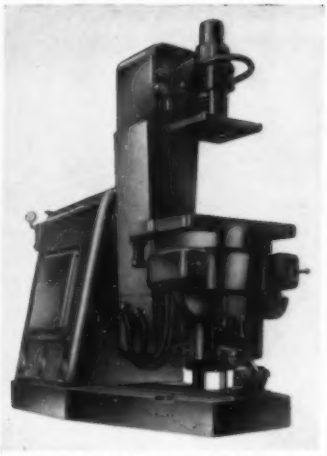
The progress made by *Rockweld, Ltd.* (U3 EH) during the two years which have elapsed since the last exhibition will be demonstrated by the wide variety of new welding plant and electrodes exhibited. The welding plant on view will include a diesel-engine-driven D.C. set with independent current and voltage control; a range of four single-operator A.C. sets (160–600 amp.); and a three-operator A.C. plant with 57kVA 3-phase transformer and three 350-amp. regulators, suitable for heavy duty operation. Under the general name of Chromac, a range of electrodes for welding stainless and heat-resisting steels will be shown, whilst progress in carbon and low-alloy steel welding will be represented by Silvac, an amazingly easy electrode to use—particularly in overhead welding, and lime-ferritic hydrogen controlled electrodes Basac 35 and Basac 45 developed for welding restrained mild steel, high-strength low-alloy steels, high-sulphur free-cutting steels, and cast iron. Considerable interest is also anticipated in the display of Oxyarc cutting equipment.

The importance of the use of manipulators in the welding shop is being increasingly appreciated, and a range of Twinner welding positioners will be shown on the stand of *Donald Ross & Partners, Ltd.* (U1 EH). They will include vices, which enable up to four pieces of metal to be speedily locked in any desired relation to one another, and whose cruciform tables can be revolved and tilted to give



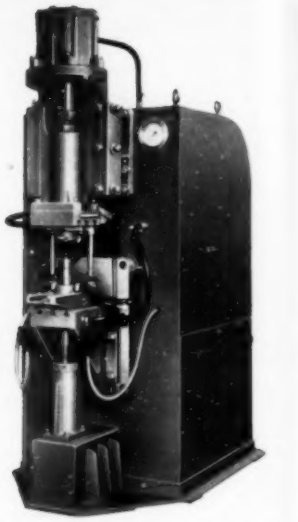
Courtesy of G. D. Peters & Co., Ltd.

Arc welding set.



Courtesy of British Moulding Machine Co., Ltd.

B.T. turnover moulding machine.



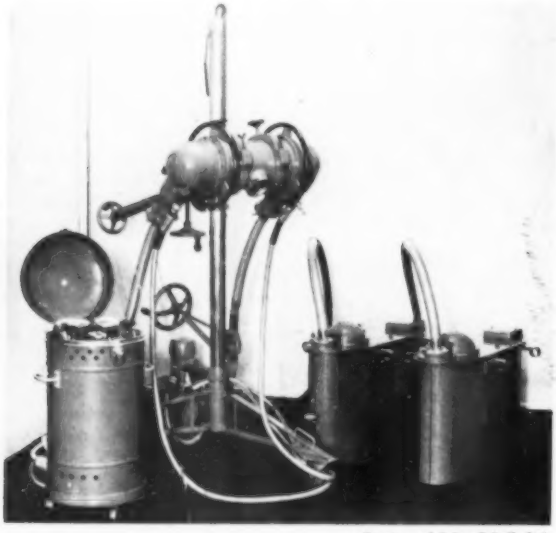
Courtesy of Siemens Schuckert (Great Britain), Ltd.

Air-operated projection welder—Type WJ7.

45° welding position ; power-operated rolls for revolving cylindrical objects whilst welding proceeds ; and a selection of pipe clamps and other aids to speedy holding and positioning.

Representative examples of the Company's resistance welding plant will be displayed by *Sciaky Electric Welding Machines, Ltd.* (W6 EH). The Sciaky type S.A.T. 75 air-operated, fully controlled, balanced load, 3-phase spot welder to be shown has a nominal rating of 75 kVA, a minimum power factor of 0·85, and is suitable for welding light alloys and mild and heat-resisting steels. For seam welding, a type R.A.M.U. air-operated motor-driven unit with a throat-depth of 24 in. will be shown. Other exhibits will include a type B.S.A.7 bench-mounted spot welder, a type P.A.100 projection welder, and a type P.S.A.70 portable spot welder as used in automobile body production.

The seam welder to be seen on the stand of *Siemens-Schucket (Great Britain), Ltd.* (V7 EH) is arranged for welding longitudinal seams but can be readily equipped for circular seams, a universal model being available for use where such changes are frequently needed. The spot welders will include a pedal-operated bench machine for fine wire work, which is also supplied in an air-operated model where continuous high-speed work would result in operator-fatigue. The display will also feature a 100 kVA air-operated projection welder and a portable spot welder.



Courtesy of Solus-Schall, Ltd.

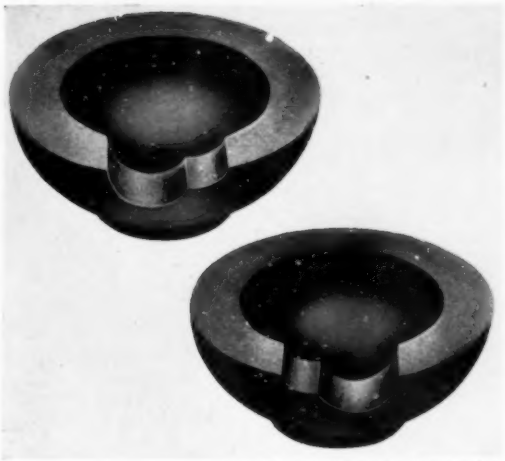
300 kVA mobile X-ray equipment.

Solus-Schall, Ltd. (V2 EH) specialise in the application of X-rays to industrial purposes and in all aspects of non-destructive testing, and conduct an industrial radiographic service which will be illustrated on the stand by photographs and radiographs. Radiographic equipment on show will include a fine-focus X-ray unit ; a 300 kV mobile X-ray set which is suitable for site inspection of welds ; a 140 kV mobile set whose extra long H.T. cables result in an increased sphere of action ; containers for radioactive substances used in gamma radiography ; and equipment for X-ray crystallography using Geiger counters or film cameras. Portable magnetic crack detectors will also be displayed.

Suffolk Iron Foundry (1920), *Ltd.* (X2 EH) are perhaps most widely known in connection with Sifbronze welding and the display on this stand will include oxy-acetylene welding supplies and equipment, including Demon blowpipes, regulators, goggles, hose, gloves, cylinder keys and the Sifbronze range of welding rods and fluxes for all classes of oxy-acetylene welding.

Oxy-acetylene welding and metal-cutting apparatus, including a range of Incanto acetylene generators of types suitable for permanent installation and portable use, will be seen on the stand of *Thorn & Hoddle, Ltd.* (U2 EH). Blowpipes for use with acetylene, propane and coal gas will be featured, and will include air-acetylene blowpipes of a new type, suitable for cable jointing, paint burning, general heating, and brazing. A special feature will be a newly developed pipe-cutting and end-bevelling machine of great interest to all concerned with the welding of steel tubing.

On the *Weldcraft* stand (W9 EH) a special feature will be made of high-pressure acetylene line installations for



Courtesy of General Refractories, Ltd.

Spinella 'D' shapes.

Courtesy of The Morgan Crucible Co., Ltd.

Power-tilted central axis tilting furnace.

which the Aut-O-Cet generators and equipment are Home Office approved. The approved equipment includes hydraulic valves designed to prevent backfires from reaching the generators. The new Fluxcraft gas-fluxer which eliminates the use of powder flux in bronze welding, by inducting a liquid flux into the gas line will also be shown. Other exhibits will include the "Craft" series of welding rods, comprising: Bronzecraft, hard-craft, steelcraft, ferrocraft, alicraft, covering all gas-welding requirements; Aut-O-Cet welding and cutting equipment; and both portable and stationary Sight Feed medium pressure acetylene generators.

FOUNDRY EQUIPMENT SECTION

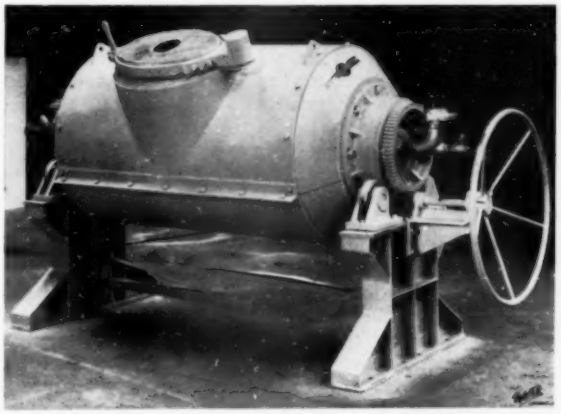
The exhibition this year incorporates the Foundry Trades Exhibition. As three productivity teams have recently visited the U.S.A., under the auspices of the Anglo-American Council on Productivity to study foundry techniques, it is anticipated that great interest will be shown in this section, as the recommendations contained in the reports of the various teams are now being applied. The ironfounding industry has set up a new production record by producing iron castings at the rate of 3,700,000 tons per annum in the first quarter of 1951 and this record was only possible by improved efficiency and through the increased use of mechanical ideas. A separate section of the exhibition will be devoted to foundry equipment.

The exhibit on the stand of *Bradley & Foster, Ltd.* (G14 GH) will consist of a complete display of the well-known brands of Bradleys refined irons, both in the sand-cast and machine-cast forms. Besides refined malleable pig irons and cylinder pig irons, examples of refined alloy irons and electro-refined ingots will be shown, together with Hypersilid high-silicon acid-resisting iron castings. On the same stand, *Bradleys (Darlaston), Ltd.* manufacturers of metallic abrasives for shot blasting will have the complete range on view. In addition to standard grades of chilled shot and grit, there will be samples of Malleabrasive shot and Brafos hard-drawn pellets in carbon steel, stainless steel and copper.

A range of foundry requisites and sundry materials will be shown by *British Foundry Units, Ltd.* (E17 GH). For oil sand core productions there will be Crulin core oils and compounds, Crudol and Crudex core powders and Corbeerite binders, while for general moulding, special foundry blackings, high-grade plumbagoes, and silica-free parting powders will be on view. Fluxes for ferrous and non-ferrous alloys and Alsica feeder head compounds for use with steel and iron will also be exhibited, along with cores and castings made with the use of these products.

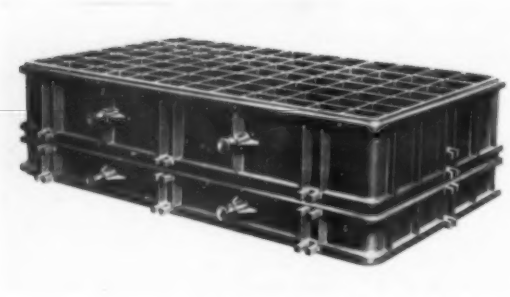
The British Moulding Machine Co., Ltd. (G16 GH) will be showing a range of B.T. turnover moulding machines which have hitherto been unobtainable in this country, although they have been sold in the U.S.A. and on the Continent. An interesting feature is the built-in jolt timer, whilst automatic lubrication, built-in air filters, a fully automatic anvil, and other features will reduce breakdowns to a minimum. All operations are push-button controlled, and the considerable streamlining should assist materially in keeping the machine clean. Large and small machines will be in operation, a large one in conjunction with a hopper feed and an entirely new method of mould removal which is expected to attract considerable attention.

A display of super-refractory materials in silicon carbide and fused alumina will be shown by *The Carborun-*



Courtesy of Monometer Manufacturing Co., Ltd.

Oil-fired semi-rotary furnace.



Courtesy of Sterling Foundry Specialities, Ltd.

Heavy duty boxes for casting machine tool parts in dry sand, 3 ft. 6 in. × 7 ft. 6 in. with a 14 in. top part and 8 in. bottom part.

dum Co., Ltd. (H17 GH), together with bricks and special shapes made from the bonded refractories and known as Carbofrax and Alfrax. They are designed to withstand the highest commercial temperatures, resist abrasion and do not spall under rapid changes of temperature. Crucibles of varying shapes and sizes will be shown, suitable for use in non-ferrous metal melting operations. Finally, there will be a display of Globar high-temperature electric heating elements.

In the comprehensive range of magnetic separators shown by *Electromagnets, Ltd.* will be a newly developed super intensity magnetic feeder unit which takes the form of a shortband conveyor. The conventional magnetic pulley which is widely used in such plants, is replaced by a new magnetic head around which is contoured the rubber and canvas conveyor belt. Limitations on space of magnetic circuit and windings normally imposed by pulley or drum diameter are completely removed and a field intensity three or four times greater than that given by the same size drum or pulley is obtained. Relatively small separators can handle large outputs, thus reducing costs and economising space.

The exhibits of *The Fordath Engineering Co., Ltd.* (E16 GH) will include a display of production cores bonded with Glyso cereal binders, compounds and oils. Demonstrations will include the making of cores bonded with Glyso-Resyn and dried in two minutes by high-frequency equipment, the use of Airbond powder for facing green sand moulds, and the use of Fordavol core and mould spray oil. A full range of sand mixers (six sizes between 20 lb. and 1 ton) will be on view, some in action, together with core extrusion and core blowing machines.

The display on the *Foundry Services, Ltd.* stand (K16 GH) will show the practical and commercial application of scientific research to the different types of molten metal and dies designed to receive it. The exhibits will include specimen castings demonstrating the effective use of the latest Foseco degasers, grain refiners, covering fluxes, etc. as applied to all types of metal. Also there will be a selection of feeding compounds of interest to all foundrymen, together with an illuminated working model to show the application and use of Feedex—a mouldable exothermic compound.

On the *Fullers' Earth Union, Ltd.* stand (D11 GH) the exhibit deals especially with Fulbond, the well-known clay bonding material made from British montmorillonite clay, that is, the kind of clay often described as "bentonite." The principal grades of Fulbond will be shown and the sand-testing equipment installed will show the effects of adding Fulbonds to several different types of sand, such as silica sands for synthetic mixes and burnt red natural sand for regeneration. A number of castings in various metals, which have been made in Fulbond sands, will be found on the stand.

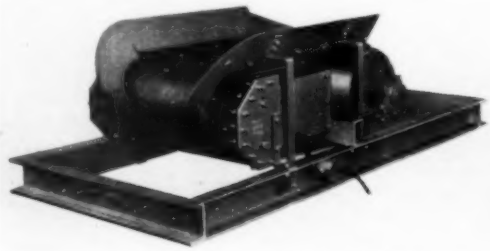
Exhibits on the *General Refractories, Ltd.* stand (F12 GH) will cover the refractory requirements of all types of industrial furnaces. Basic refractories will include a comprehensive range of magnesite and chrome-magnesite bricks. Specially featured will be the Ferroclad metal-cased chemically bonded basic bricks, and the G.R.341 dolomite bricks made from British dolomite. Fireclay refractories, refractories for all types of suspended wall and roof construction, and a selection of high alumina, sillimanite and carbon refractories will be shown together with fire cements, jointing compounds, monolithic compositions and moulding and silica sands. Of particular interest will be an exhibit of Amberlite heat insulating products.

The Foundry Supplies Division of *The Harborough Construction Co., Ltd.* (H18 GH) will be exhibiting outstanding examples of iron, steel, aluminium- and copper-base castings, with corresponding core assemblies, showing the use of the Company's core compounds, core oils, mould and core dressings, synthetic resin binders, cereal binders, pattern stone powder, parting powder, iron cement, etc. A range of cast aluminium- and copper-based test pieces will illustrate the effects of Harmark fluxes.

Although not exhibited in the Foundry Trades Section, the products of *Leicester, Lovell & Co., Ltd.* (Outer 10 NH Gallery) will be of interest to foundrymen. They will consist of Thor synthetic resin core binders which will be used in core-blowing and radio-frequency baking demonstrations, core- and mould-sprays, and other foundry products, whose advantage will be illustrated by a variety of cores, moulds and castings taken from regular production.

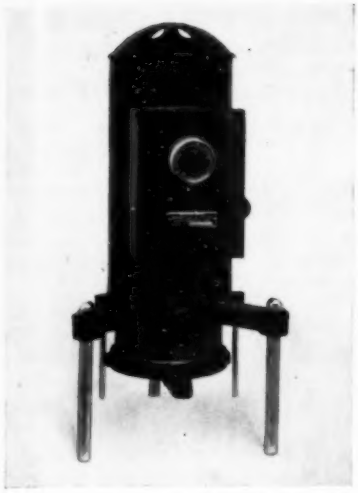
On the stand of *Monometer Manufacturing Co., Ltd.* (G13 GH) will be exhibited the latest design of oil-fired, fully mechanised, continuous rotary melting furnace, complete with retractable end flue, suitable for melting iron, steel, and all non-ferrous metals. Other items on show will include semi-rotary oil-fired or gas-fired melting furnaces for non-ferrous metals, and a hydraulically operated ladle for supplying hot metal from bulk melting furnaces to die-casting pots and holding furnaces, and for iron for the production of castings.

The stand of *The Morgan Crucible Co., Ltd.* (A17 GH) will be devoted mainly to a display of crucibles, foundry accessories and crucible furnaces. Of particular interest to all foundrymen will be the latest addition to the



Courtesy of Electromagnets, Ltd.

Super-intensity magnetic feeder unit.



Courtesy of Ridsdale & Co., Ltd.

New design Ridsdale-Dietert moisture teller.

Courtesy of the Fordath Engineering Co., Ltd.

CorALL core blowing machine.

Courtesy of Spencer & Halstead, Ltd.

8 ft. Centriblast rotary table shot blast machine.

Salamander range—the Salamander Suprex crucible—developed for use in specially arduous conditions. Among the crucible furnaces on show will be the recently developed power-tilted central axis tilting furnace which is being exhibited for the first time, and the rotary crucible furnace. In addition a newly developed super-duty refractory will be shown; this is the Morgan M.R.1 refractory.

The pattern-making capabilities and capacity of the Company will be shown by the display of wood and metal patterns to be seen on the stand of *G. Perry & Sons, Ltd.* (A19 GH). They will include metal patterns for the mass-production of a large number of castings for agricultural implements and automobile parts, and combined wood and metal patterns for general engineering. Also on view will be patterns for unusual castings, showing the initial plaster cast, the casting as received from the foundry, and the final metal pattern after intricate machining. Double-sided metal pattern plates made in the Company's foundry will also be displayed, together with photographs showing a variety of special patterns made in the last 60 years.

Amongst items of special interest in the display of *Rapid Magnetic Machines, Ltd.* (G15 GH) will be a range of permanent magnetic equipment, which will include Permaflux drum- and pulley-type separators, and a new welding clamp which is adjustable at all angles. Two typical types of swarf separators, which are also fitted with permanent magnets, will be shown in operation. Electro-magnetic percolators for treating wet materials such as potters slip, glaze, etc., will also be available for inspection as will the overband-type separator, which is widely used in foundries for extracting iron sprigs, etc. from foundry sand. Electro-lifting magnets, clutches, and brakes will also be exhibited.

Sand-testing equipment manufactured to the designs of the Harry W. Dietert Co., Detroit, will be shown by the makers, *Ridsdale & Co., Ltd.* (A16 GH), the sole licensee in Britain. Many of the items of equipment have been redesigned recently to give greater durability, simplicity and precision. The exhibits will include a moisture teller (of the hot air drying type), a standard rammer, a permeability meter, a universal strength machine, a sand washer, and a green-hardness tester.

Shown for the first time, on the *Spencer & Halstead, Ltd.* stand (H19 GH), will be the Spenstead welding fume extractor unit, and the Spenstead Mark II dust-collecting unit. The former incorporates an oiled glass filter element of the cheap replaceable type and has a capacity of 200 cu. ft./min. of air, whilst the dust-collecting unit embodies in a modern cabinet a primary expansion chamber, a battery of filter screens, and a high efficiency direct-coupled motor-driven fan. Other exhibits of special interest to foundrymen will be the Centriblast airless rotary table blast cleaning machine, and the Centriblast airless rotary barrel blast cleaning machines.

The display of the *Standard Brick & Sand Co., Ltd.* (K14 GH) will consist of a range of industrial silica sands, emphasis being placed on grades suitable for foundry-work, either for coremaking or for the production of synthetic moulding sands. Samples of naturally bonded moulding sands will also be displayed together with an interesting selection of castings moulds and cores produced with various grades of sand.

Sterling Foundry Specialities, Ltd. (D10 GH) will be showing a representative range of their moulding boxes, which are made from hot-rolled sections of their own design. The range of sizes now includes the largest that can be carried by ordinary methods of transport; other exhibits will include the Sterling high-speed shakeout moulding machine, which is widely used at home and abroad, and unit frame scaffolding.

Various types of equipment for cleaning castings will be displayed by *Tilghman's Patent Sand Blast Co., Ltd.* (E15 GH); a direct-pressure shot blast cabinet; a Tiltblast liquid honing cabinet for producing extremely fine finishes on ground surfaces; two Wheelabrator table shot blast machines; a special Wheelabrator shot blast cabinet for small outputs; a Wheelabrator Tunblast for general descaling; a portion of a Wheelabrator overhead conveyor plant for continuous operation; and a tubular bag-type dust arrester. Certain of the foregoing items

will be run for demonstrations, as will an air compressor and a Heenan & Froude cooler.

Dust-collection equipment of wet and dry-wet types applicable to all industrial dusts will be shown by the *Traughber Filter Co., Ltd.* (D12 GH). A model wet filter, complete with mechanical conveyor for sludge removal will be cut away at various points to demonstrate the path of the dust-laden air and the methods of suppression. Types for use with single machines, groups of machines, and foundry shakeouts will also be on view.

British Iron and Steel Team's Return

First Impressions on American Productivity

THE Iron and Steel Productivity Team representing the British heavy steelmaking industry returned from the United States on July 5th, after spending five and a half weeks visiting steelworks in California, Texas and Colorado, as well as the traditional steelmaking areas.

In view of the close technical links that already exist between the steel industries in the two countries, it was not expected that the visit would reveal striking new developments, but many points of interest in blast furnace, open hearth furnace and rolling mill design and operation were seen and will be discussed in the Team's report.

The Team found that high productivity in the American Industry is primarily due to four factors—the size of the plant units; the purity of raw materials (resulting in a low metallurgical load); the tendency to drive units fast; and the use of high-grade fuel, including natural gas and fuel oil. The development of large units of production is assisted by a price and marketing system designed to avoid the interference to the flow of production arising from a high proportion of small orders, and by less exacting standards in finishing operations. A high proportion of the smaller orders are met from stocks held by warehouses.

The normal manning of the plant is generally the same in the two countries; in a few cases it is lower in America. The training of employees, other than those of supervisory grades, is less developed and incentive wage schemes are not used so extensively as in Britain. The framework of the American industry's structure in the union-management contract is "job evaluation," which the Team studied with interest. The advantages both to management and labour in the United States of both process and maintenance workers being covered by the same union were apparent. The safety record in American plants is high.

As the distances over which ore and coal are carried are very great, the Americans have developed techniques to reduce freight costs, many of which should be applicable in Britain. Fuel in America is relatively cheap, and fuel economy is not so vital a part of plant integration as it is in Britain.

U.S. Pressed Metal Team's Visit

THE productivity team from the American Pressed Metal industry, the second of the "reciprocal" teams to visit industries in this country under the auspices of the Economic Co-operation Administration, has completed a five weeks' tour of British factories.

The team consists of fifteen members, led by Mr. F. C. Greenhill, President of the Acklin Stamping Company, of Toledo, Ohio. They have inspected, in the light of the Report of the British Pressed Metal Team that visited the U.S. in 1949, some thirteen British pressing plants, small, medium and large, in various centres. They have expressed keen interest in the methods and techniques of production brought to their notice, commenting that in some cases there is a great similarity between British plants and those in operation at, say, Detroit. The team has been impressed with the speed and efficiency of British manufacture, which, as a whole, were found to be higher than had been anticipated. It is also appreciative of the hospitality, industrial and social, received in the course of a tour necessarily arduous.

World Metallurgical Congress

Visits to U.S. Industrial Plants

MORE than 145 major American metal producing plants are making arrangements to receive visits from 250 top-level metal scientists from other countries, in a series of eight four-week study tours commencing on September 17th. These study tours, which constitute one of the largest technical assistance projects listed by the Economic Co-operation Administration, are preliminary to the scientific sessions of the World Metallurgical Congress to be held in Detroit, Michigan, from October 14th–19th, and have been developed by the American Society for Metals, sponsor of the Congress, the first international meeting of its kind.

Dr. Zay Jeffries, Director General of the Congress, who believes it is time for the "free world to wage peace with production" pointed out the ready response of the host companies to entertain the study tour parties. "These companies," he said, "know that the free nations must increase their supply of metals and step up efficiency in the use of both new metal and scrap. The tours should help achieve this objective. They will contribute to the cross fertilisation of ideas among top metallurgists."

Metal Statistics, 1951

By N. J. Langer, published by American Metal Market, New York 38. Pp. 808. Price $2.

THE 44th Annual Edition of this Year Book contains the same general assortment of statistical information on ferrous and non-ferrous metals, and miscellaneous economic subjects, as was presented in previous issues. Reliable data from the U.S.S.R. and satellite countries remains conspicuous by its absence, and world statistics on production and consumption are, therefore, unsatisfactory so far as totals are concerned; wherever such totals are shown, they are still largely conjectural. Additional information on domestic copper consumption in this edition is furnished by the Bureau of Mines, whilst statistics dealing with production and general consumption are gathered from various authentic sources. These include the American Iron and Steel Institute, American Bureau of Metal Statistics, Bureau of the Census, Copper Institute, American Zinc Institute, Lead Industries Association, and the International Tin Study Group. The book also contains a Buyers' Directory covering 130 pages in alphabetical list of products.

F.N.

The British Association Meeting

Metals and Alloys Discussed at Edinburgh

INCLUDED in the programme of the 1951 Meeting of the British Association for the Advancement of Science, was a joint meeting of the Chemistry and Engineering Sections, held on August 14th, at which recent developments resulting from studies of metals and alloys were discussed. A wide field of interest was catered for by papers on the chemistry of extraction metallurgy, the strength of metals, recent metals and alloys, and the brittle fracture of mild steel. Salient features of these papers are presented in an abridged form in the following pages.

Chemistry in Metal Extraction

By Dr. F. D. Richardson*

There are three main steps in the winning of a metal from its mined ore—concentration, smelting and refining. Chemistry enters into all of them, but this paper is restricted to the chemistry of metal extraction at high temperatures.

The systems which are most important in this connection are molten metals and molten slags and mattes. Our knowledge is weakest on the last two, so that research is particularly required on the chemistry of molten silicates, oxides and sulphides and their mixtures. Since the nature of liquid metal and slag solutions is only now becoming clear, it is worth reviewing the picture of them which has so far been developed by the application of physical chemistry.

A molten metal consists of closely packed metal atoms, each of which interacts strongly with its eight or so nearest neighbours. The liquid resembles the solid closely, and differs from it mainly in lacking the long range order peculiar to the crystalline state. Other elements dissolved in metals can be pictured as foreign atoms dispersed amongst the metal atoms and also interacting strongly with them. They may be distributed uniformly throughout the melt or they may cluster together in some degree. There is evidence, for example, that chromium and oxygen atoms cluster together when dissolved in liquid iron, and so influence each other's behaviour.

Molten silicates consist of disordered three dimensional networks of tetrahedral silicate groups (SiO_4), and these groups share corners with one another via Si–O–Si "bridges." Every corner is shared in the case of fused silica, which has a high viscosity as a result. These bridges can be broken by the addition of metal oxides. As sodium oxide, for example, is added to fused silica, the chains in the network become shorter and shorter with a corresponding decrease in viscosity, until at the composition 1 SiO_2–2 Na_2O no corners need be shared. Thereafter the addition of more metal oxide gives rise to oxygen and metal ions dispersed between silicate tetrahedra. As much confusion has arisen from theories of the formation of various kinds of molecular compounds in liquid slags, it needs to be stressed that no precise molecules can be identified in such melts. The only entities which can be recognised as having a distinctive existence are the metal ions, the silicate tetrahedra which carry a net negative charge and may be bridged together in varying degrees, and the excess oxygen ions.

The rates of reactions between slags and metals are not controlled by the chemistry of the processes which take place at the interfaces between them. Diffusion of reactants and resultants to and from the interface is rate-controlling and diffusion in the slag is usually far slower than in the metal. The rates of refining processes with slags are thus dependent on stirring conditions and the diffusion coefficients of the participating entities in the slag.

The research which is being done to-day is designed to elucidate the nature of these liquid systems still further. The thermodynamic properties of slag and metal solutions are being measured by gas-slag, gas-metal and slag-metal equilibrium studies. The atomic nature of metals and slags is being solved by measurements of viscosity and diffusion and, in the case of slags, of electrical conductivity and ionic transport as well.

The physical chemistry of metals and slags is a development of the past 25 years. During this time it has mainly been related to iron and steelmaking, and to such new and costly metals as titanium, zirconium and uranium. The latter are now being produced by methods which spring directly from chemical research. So far as iron and steel and the older metals are concerned, research has been aimed at establishing the physico-chemical background of existing processes. These have been successfully developed by empirical means, so that, in a sense, the research chemist has here been trying to "catch up with" the practising metallurgist. The older metal industries do not therefore show any dramatic advances, resulting from the application of physical chemistry. They do, however, show many improvements which have followed from a better understanding of what goes on in the furnaces of the smelter and refiner.

Recent work on sulphur in iron-making provides a typical example of the way in which such improvements can come about. Although the scarcity of sulphur may be a headache to the Government and Chemical Industry, a surfeit of this element presents a problem to the metallurgist and especially to the makers of iron and steel. The sulphur in iron ore and coke gets into iron when it is made in the blast furnace. Although the majority passes into the slag, which carries around 1 to 2% sulphur, about 0·1% is left in the metal. This causes difficulty in steelmaking as it has to be removed, as far as practicable, by the use of large quantities of a strongly basic slag.

Fundamental thermodynamic studies have lately shown that under normal conditions a sulphur atom can only enter a silicate slag of constant composition by displacing an oxygen atom. The equilibrium between sulphur and oxygen in slag metal and slag gas systems may thus be represented by the equations :—

$$(S'') \text{ Slag} + (O) \text{ metal} = (O'') \text{ slag} + (S) \text{ metal},$$

$$(S'') \text{ slag} + 1/2O_2 \quad + (O'') \text{ slag} + 1/2S_2.$$

It follows that in gas-slag systems, a high oxygen pressure tends to push sulphur out of the slag into the

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gas. It has also been shown that the partition of sulphur between slag and metal, which can be obtained under equilibrium conditions in the laboratory, is much more favourable than that attained in the blast furnace. This is apparently due to inadequate mixing between slag and metal.

A two-fold possibility of practical importance clearly emerges from these fundamental researches. It may become possible to make lower sulphur pig iron by mixing slag and metal in the ladle after tapping—an additional operation but one which utilises materials already available and at the right temperature. It may also become practicable to recover the sulphur present in the molten slag by blowing air or oxygen through it. Although only 1–2% is present, it is readily evolved as sulphur dioxide which could be used for the production of sulphuric acid. The seven million tons of blast furnace slag made annually in Britain are thus a potential source of 100,000 tons of sulphur.

The Strength of Metals

By Professor A. H. Cottrell†

In a ductile metal, the yield strength and fracture strength both depend on the process of plastic deformation that takes place in its constituent crystals. It is well known that a metal crystal deforms plastically by the sliding of one piece of crystal past another on certain crystal planes (slip planes) and in certain crystal directions (slip directions). Because the slip direction is crystallographically determined, even when the maximum resolved shear stress acts in other directions in the slip plane, the material in the slip plane evidently remains crystalline when slip takes place.

The atoms in a slip plane cannot all slip simultaneously over their neighbours in the next plane ; slip must begin at certain places and then spread throughout the rest of the plane. It is thus possible, in principle at least, for us to draw lines in an active slip plane, marking out the boundaries of regions where slip has occurred to the extent of 0, 1, 2 . . . , etc., lattice spacings. We call these boundary lines *slip dislocations*. The structure and properties of slip dislocations can be deduced from the theory of elasticity and from considerations of lattice geometry. Three properties are particularly important : (1) When a slip dislocation is moved in a slip plane the amount of plastic deformation in the crystal is altered ; (2) the stress needed to move a dislocation through a slip plane of an otherwise perfect crystal is smaller than the lowest observed yield strength ; (3) the stress needed to create a dislocation in a perfect lattice is larger than the highest observed strength.

This last property implies that slip dislocations must be present in the crystal before it is subjected to a plasticity experiment. Support for this idea is provided by a recent theory of crystal growth (theory of Frank), which shows that imperfect crystals, containing dislocations, will grow more quickly than perfect ones. This theory predicts that growth takes place by deposition along spiral terraces on crystal faces, the centre of each spiral being the point where a dislocation line emerges from the interior of the crystal. Recent observations of such growth spirals on inorganic crystals provide striking confirmation of this theory.

The dislocations formed during crystal growth are not constrained to lie in slip planes. Such a dislocation line may follow an arbitrary path through the crystal, some parts lying in slip planes, and so constituting slip dislocations, while other parts do not lie in slip planes and are immobile. A slip dislocation which is part of a more general dislocation line is anchored to the point (*point of emergence*) in its slip plane where the line turns out of the plane into some immobile orientation. It can therefore glide in its slip plane only by rotating about this point of emergence, rather as the hand of a clock glides in the plane of the clock face by rotating about the centre. The number of rotations which can occur is limited only by boundary conditions, and this is consistent with the observed fact that the amount of slip on active slip planes can be very large, of the order of 1,000 lattice spacings. The analogy with the hand of a clock is not perfect ; the dislocation line will curl up into a spiral as it rotates, because, for a constant linear velocity of the dislocation, the angular velocity is greatest for those parts that are nearest to the point of emergence.

Under certain circumstances this rotating dislocation may climb from one slip plane to the next as it rotates, in which case the plastic deformation is not concentrated into a single active plane, but is spread homogeneously through a sequence of planes. This is most likely to occur when the slip dislocation produces a slip of less than one lattice spacing each time it moves through a plane. It may be the mechanism whereby deformation twins are formed.

Since a perfect lattice offers little resistance to the motion of a slip dislocation, the observed hardness of metals must be due to imperfections in the structure which obstruct the dislocations. Various kinds of obstacles may be encountered and affect dislocations in different ways. Mobile impurity atoms in solid solution may migrate to resting dislocations and anchor them firmly to their initial positions. A large stress is then needed to break the dislocations away from these positions, but once they have broken away they can be moved easily by smaller stresses. The material should therefore soften suddenly at the start of plastic deformation. This ' yield phenomenon ' is observed in soft iron which contains carbon and nitrogen.

Immobile solute atoms, which are dispersed as individuals, or clustered together into precipitates, offer a resistance to a dislocation that is statistically independent of its position in the crystal. No yield phenomenon is observed, but the crystal is hardened because the dislocation has to be driven through the internal stress fields caused by these particles. A critical size of dispersion exists at which the hardening is a maximum. If the dispersion is too fine, the random stress fields acting on the dislocation practically cancel one another, and there is little hardening. If the particles are too far apart, the dislocation is able to curl between them and ' by-pass ' them, and again there is little hardening.

Grain boundaries form strong obstacles to the passage of dislocations. Slip can be transmitted from one grain to another, however, in the following way. If a sequence of dislocations, in an active slip plane, approaches a grain boundary the pressure of the members of the sequence against their leader, which is obstructed by the boundary, causes a large intensification of stress in the neighbourhood of the obstruction. When the number of dislocations in the sequence is large (1,000 is a reasonable value) the stress is enlarged so much that slip is forced to take place in the crystal on the other side of the

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boundary. The number of dislocations that can be piled up in a slip plane increases both with the applied stress, and with the length of that plane, that is, with the grain size. It follows that grain boundaries are less effective as obstacles when the grain size is large.

Strain hardening is proving to be one of the more intractable problems facing the theory. It depends upon the group behaviour of the large number of dislocations created during plastic flow. Recent experiments suggest that the initial dislocations tend to assemble into sheet-like arrays, roughly perpendicular to the slip direction, where they are firmly locked by their mutual interactions. These sheets act as barriers to the propagation of later dislocations, and as more dislocations gather up in them, they became observable under the microscope, where they are known as deformation bands. We do not as yet fully understand how these special arrays of dislocations are formed in the first place, or why they should be so stable mechanically, but there are strong reasons for believing that they are the main cause of strain hardening.

Recent Metals and Alloys

By Professor A. G. Quarrell*

Many operations in the production and working of metals are only possible because the engineer provides the metallurgist with the powerful and sometimes elaborate machines that are required. It is equally true to say that many of the achievements of modern engineering would not have been possible had not the metallurgist developed new and improved alloys with properties suitable for the particular applications. Whereas engineers at first based their designs upon known alloys they now tell the metallurgist what combination of properties is required to permit optimum, or at least efficient, performance of a given machine. The metallurgist is by now quite familiar with the technique, and knows only too well that as soon as he has provided what he was asked for, more exacting demands will be made. Much of the metallurgical activity of this country is, in one way or another, concerned with meeting such demands.

For most of the five or six thousand years that metals have been used by man, metallurgy has been an art rather than a science and new alloys have resulted from chance observation rather than from deliberate effort. The last few years have seen vast strides in our understanding of the theory of alloys, but unfortunately the alloys which are most important technically are extremely complex and industrial practice still outstrips theoretical understanding. As a result, alloy development is still largely empirical and the rapidity with which existing alloys are improved and new alloys developed is due mainly to the magnitude of the effort being made and to the skill of the metallurgist in exploiting to the full any beneficial effects he observes as a result of changes in composition or in heat-treatment.

The needs of the aircraft industry for alloys of high strength-to-weight ratio suitable for air-frames and for alloys capable of withstanding high stresses at elevated temperatures in aero-engines have provided the incentive for the steady improvement of light alloys and of the special alloy steels. High-strength aluminium alloys of the aluminium-zinc-magnesium-copper type are the most recent in the line of descent from Wilm's duralumin and form a large part of most modern aircraft. Greatly improved properties coupled with the low density of magnesium have become available in the last few years with the introduction of the magnesium-zirconium-zinc alloys; the zirconium exerts a powerful grain refining effect, reduces the microporosity which was such an undesirable feature of earlier alloys and facilities both hot and cold working.

Alloys suitable for use at elevated temperatures as in the gas turbine have been the subject of much discussion recently and on the whole the tale is one of steady improvement of known alloys rather than of the discovery of alloys of quite new types. Austenitic steels, particularly an alloy containing nickel, chromium, cobalt, tungsten, molybdenum and columbium, have given successful service as gas turbine discs under conditions of high stress and high temperature. Ferritic steels have been continuously improved and there are now alloys with creep and scaling resistance almost approaching those of the austenitic steels and much more economic because of their lower alloy contents. Alloys based on the 80/20 nickel-chromium alloy with the addition of titanium and aluminium have proved most successful for use as gas-turbine rotor blading and continuous research by a large team has enabled the maximum working stress and temperature of such alloys to be raised repeatedly.

Copper alloys also affected by the requirements of the gas turbine. Light alloys are extensively used for compressor blading, but the higher working temperatures involved in contemporary design is causing special interest to be shown in the complex aluminium bronzes. The single phase aluminium bronzes are similarly of interest in connection with the heat exchangers which form an essential part of long-life gas turbines suitable for marine or land installations.

Full information has recently been published concerning the copper-nickel-iron alloys that were developed to meet the exacting requirements of the Navy at war. Copper-base alloys containing up to 10% nickel and up to 2% iron can be worked almost as readily as copper by the techniques used by the coppersmith and yet have excellent resistance to the impingement type of corrosion attack caused by seawater containing entrapped air. These alloys have already shown their value for auxiliary piping in ships and, in the U.S.A. at least, they are being advocated for use as condenser tubes.

Systematic study of the effect of alloying additions upon the properties of cast iron has considerably extended their field of usefulness but even more important, potentially, is the development of nodular cast iron which has resulted from a scientific study of the mode of graphite formation. By adding to the ladle small amounts of cerium or magnesium the iron can be made to solidify with the graphite in nodular instead of flake form and the mechanical properties are comparable with those of steel although the excellent casting characteristics of normal cast iron are retained.

Some of the metals hitherto considered only as alloying elements are becoming of increasing interest as the possible bases of new systems of alloys. Thus, certain chromium-rich alloys have good creep properties at temperatures as high as 900 or 1,000° C., although their practical use is prevented by their extreme brittleness at ambient temperatures. Again, in recent years ductile titanium has become available in reasonably

* Sheffield University.

large quantities for the first time and much effort is now being devoted to assessing its potentialities. Titanium is relatively light—it has a specific gravity of 4·5—its resistance to corrosion by chloride solutions is excellent ; its tensile strength is greater than that of mild steel and can be further increased by alloying. Large quantities of titanium ores are available and if improved large-scale methods of extraction can be devised a new and important industry will almost certainly grow up, helping to relieve the shortage of those metals that we have for so long taken for granted.

Brittle Fracture of Mild Steel

By T. S. Robertson, M.Sc.(Eng.)*

Tests for brittleness mostly follow one main pattern. A notched testpiece is pulled or bent until, after some degree of strain, a crack propagates from the notch. The nature of the crack can be changed from tough to brittle by the controlled variation of, analysis, speed of testing, size of testpiece, geometry of the notch, heat treatment and even the temperature at which the test is carried out. As temperature is one of the more easily controlled variables, other variables are studied by producing a temperature transition curve for each of the variations in turn. More generally, it is claimed that temperature transition curves resulting from different forms of test put the steels tested in the same order of brittleness, but it is admitted that the temperature ranges obtained cannot be applied in practice. The designer is only given an order of merit. No safe stress is quoted nor is a stress allied to a safe working temperature.

2. An investigation into the effect of very sharp notches on the results of brittleness tests shows that even with a sharp fatigue crack as notch, local yielding occurs at the root of the crack before brittle fracture propagates through the adjacent slightly yielded material. Experiment also establishes that with these sharp fatigue cracks a sudden loss in strength is experienced as the temperature of test is lowered. This is contrary to experience with standard notched test-pieces, but is believed to represent a practical condition in the catastrophic failure of ships where the nominal stress level in way of the fracture has been as low as 5 tons per square inch. Attention has therefore been directed to the development of a test that will employ as sharp a notch as the material is capable of producing, namely, a propagating brittle crack.

3. In the method employed, a crack is started in the material under conditions of great brittleness and the resistance to its continued propagation into a zone of increasing toughness is studied in terms of a known stress imposed transversely to the direction of propagation of the crack.

4. The test-piece is a foot long by 3 inches wide, and is flame-cut from the plate. One end is rounded and a 1 inch diameter hole is drilled centrally in the width near this end so as to leave ¼ inch thickness of metal under the radius. A jeweller's sawcut is made centrally in the width on the side of the hole remote from the radiused end. The test-piece is welded into two transverse loading lugs 10 inches wide, with the rounded end protruding to one side. The connection between the lugs and the test-piece includes a strip of material thinner than the test-piece, which is yielded to relieve welding stresses and to ensure uniform transverse stress in the test-piece.

5. Liquid nitrogen is poured at a regulated rate into the hole in the end of the test-piece, the remote end being heated by a gas flame. By this means a very uniform temperature gradient from about − 80° C. at the notch to about + 60° C. at the remote end is obtained. A transverse stress of known value is applied through the loading lugs and the rounded end is given a single sharp blow delivered by a bolt gun.

6. The shock starts a brittle crack at the root of the notch. Under the influence of the transverse stress the crack propagates into the material through zones of gradually increasing temperature till a temperature is reached at which it stops. The progress of the crack up to this point is at exceedingly high speed, photographic records at 4,000 frames per second prove too slow to measure it. The material ahead of the crack now yields under the applied transverse load. Sometimes a second crack propagates at high speed into this yielded material.

7. The general pattern of results is that at high transverse stress values the temperature at which arrest of the crack takes place varies only slightly with reduction of stress. Eventually a stress level is reached at which a sudden drop in arrest temperature is experienced. After this drop the temperature for arrest again varies little with reduction of transverse stress. In fact a stress-temperature transition curve has been produced.

8. In a steel which propagated brittle fracture in a structure at about + 10° C. the crack was arrested in this test at + 20° C. at transverse stresses above and including 7½ tons per sq. inch, but the arrest temperature fell to − 40° C. at a stress of 5 tons per square inch.

9. The test offers the designer a link with practice in its method and it gives him a basis for the design of structures in terms of the temperatures and stresses to be met with in practice. As a proving test a single test-piece tested at the proving stress will establish the suitability of the material for the job. The test-piece is inexpensive to produce and it will be possible to use a very simple form of transverse loading device.

* Naval Construction Research Establishment, Rosyth.

Barrow Iron and Steel Works

The Iron and Steel Corporation of Great Britain have agreed to take over the Barrow Iron and Steel Works from the Ministry of Supply. The United Steel Companies, Ltd., a publicly-owned company, will continue to manage the works as they have done for the Ministry of Supply.

The hoop mills are being modernised and improved at a cost of £150,000 and these mills are believed to have good prospects. A further £60,000 is being spent on an experimental pilot plant to be installed to try out a new process for continuous casting of steel billets for the hoop mills.

Steel production is expected to be limited to that required to feed the hoop mills and owing to raw materials shortage two out of seven open hearth furnaces may be shut down shortly. Consequently some workers may be permanently displaced during the next few months. There are a number of vacancies for men in the Barrow area and it is hoped that jobs will be found for all the employees who are laid off. The timing and application of the change are being discussed by the United Steel Companies, Ltd., and the trade unions.

NEWS AND ANNOUNCEMENTS

Symposium on the Corrosion of Buried Metals

A SYMPOSIUM on the Corrosion of Buried Metals, organised by The Iron and Steel Institute in conjunction with the British Iron and Steel Research Association and the Corrosion Group of the Society of Chemical Industry, will be held at the offices of The Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1., on Wednesday, December 12th, 1951; Sir Charles Goodeve, O.B.E., D.Sc., F.R.S., Director of the British Iron and Steel Research Association, will be in the Chair. The sessions will begin at 10-0 a.m. and 2-30 p.m. and will be open to all interested.

Six papers will be presented in brief individually and discussed in pairs. They are: (*a*) "Tests on the Corrosion of Buried Iron and Steel Pipes," by J. C. HUDSON and G. P. ACOCK, and "Investigations on Underground Corrosion" by K. R. BUTLIN, W. H. J. VERNON and L. C. WHISKIN; (*b*) "Cathodic Protection," by K. A. SPENCER, and "Cathodic Protection of Buried Metal Structures," by M. R. DE BROUWER; and (*c*) "Corrosion in Buried Copper and Ferrous Strip in Natural and Salted Soils," by G. MOLE, and "Tests on the Corrosion of Buried Aluminium, Copper and Lead," by P. T. GILBERT and F. C. PORTER.

There will be no charge for admission but intending participants are requested to complete part A of a Reply Form to be obtained from the Secretary of the Iron and Steel Institute. The papers presented, together with the ensuing discussion, will be issued as a single bound volume (No. 45 in the Special Report Series of the Iron and Steel Institute) at 15s. (post-free). Orders received before the meeting, if accompanied by a remittance will be supplied at the reduced rate of 10s. (post-free) and one set of advance papers will be supplied without extra charge.

Iron and Steel Consumers' Council Formed

ON July 31st, the Minister of Supply, Mr. G. R. Strauss announced the members of the Iron and Steel Consumers Council, which has been set up under the Iron and Steel Act, 1949, to consider any matter—including prices—affecting the interests of consumers.

The Minister has made the following appointments:—

Independent Chairman: SIR WILLIAM PALMER, K.B.E., C.B.

Members of the Council: SIR AMOS AYRE, K.B.E., Mr. RALPH BENNETT, Mr. A. L. SHUTTLEWORTH, SIR ANDREW MCTAGGART, Mr. C. M. SPIELMAN, M.C., Mr. ROBERT ARBUTHNOTT, M.B.E., T.D., Mr. W. MORAY LINES, and Mr. W. D. WILSON, B.E.M. (Representing Iron and Steel Consuming Industries); Mr. M. C. WADE, M.C., Mr. J. W. ANNETTS, and Mr. H. BASIL DARBY (Representing Iron and Steel Merchants and Stockholders); Mr. W. B. BEARD, O.B.E., Mr. J. TANNER, and Mr. F. HAYDAY (Representing Workers in Consuming Industries); SIR JOHN HACKING, and GENERAL SIR DARIL G. WATSON, K.C.B., C.B.E., M.C. (Representing Nationalised Industries).

In accordance with the terms of the Act the Iron and Steel Corporation of Great Britain has nominated Sir JOHN GREEN and Mr. W. H. STOKES, C.B.E., two of its members, to serve on the Council.

The Council may consider questions concerning any of the principal products of the publicly-owned industry and will report its conclusions to the Corporation. In particular the Council must consider matters arising from representations by Consumers or referred to it by the Minister or the Corporation. It is its duty to consider any representations made to it by persons who have applied under Section 29 of the Act to the Minister for a licence to carry on iron ore mining and smelting, or the production or hot rolling of steel.

The Council will report to the Minister or to the Corporation as appropriate. The Minister may give specific directions to the Corporation on matters arising from the Council's reports. The Council may appoint Committees (which need not include its own members) to consider local or sectional problems. The Minister has decided after consultation with the appropriate organisations, that the private section of the iron and steel industry shall not at present be represented on the Consumers' Council. These organisations will continue to discuss problems of common interest directly with the Iron and Steel Corporation of Great Britain.

The offices of the Council will be at 1, Chester Street, London, S.W.1.

Technical Personnel Committee Reconstituted

IT has been decided to reconstitute the Technical Personnel Committee, which, under the chairmanship of Lord Hankey dealt so successfully with questions of scientific and technical manpower during the last war and during the immediate post-war period. The new Committee will have rather wider terms of reference than the old one. It will review the requirements for scientists and engineers at home, and especially those arising from the defence programme, in relation to the available supply. It will also consider what more can be done to meet certain important overseas needs for people of the same type.

Lord Hankey has agreed to serve as Chairman of the reconstituted Committee and the members, representative of industry, the universities, and Government departments include Sir Arthur Fleming, Sir Wallace Akers, Capt. A. M. Holbein, Sir Edward Appleton, Sir Arthur Trueman, Professor S. Zuckerman, Mr. S. L. Lees, Mr. E. A. Berthord, Mr. R. A. Whittle, Mr. S. A. Dakin, Mr. A. C. B. Symon, Mr. H. M. D. Parker, Mr. W. D. Wilkinson, and Mr. E. D. T. Jourdain.

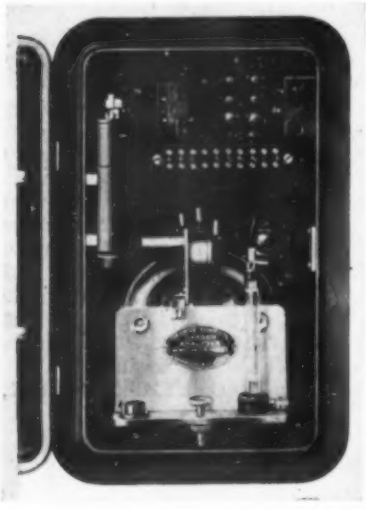
General Discussion on Metal Economics

A GENERAL Discussion on Metal Economics, organised by the Council of the Institute of Metals, will be held at the Park Lane Hotel, Piccadilly, London, W.1., on Wednesday, October 17th, 1951. The morning and afternoon sessions will be devoted respectively to (1) Primary Resources of Ferrous and Non-Ferrous Metals, and (2) Scrap, Reclamation, Secondary Metals, and Substitute Materials.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Magnetic Oxygen Recorder

GEORGE KENT, LTD., of London and Luton, announce the development of a new paramagnetic continuous oxygen recorder for use in industrial processes. Robust, reasonably priced and accurate, the new instrument is in complete contrast to the expensive and complicated equipment in common use until recently. Although many new applications will no doubt suggest themselves, the new recorder will meet all the usual demands, e.g. for the analysis of furnace atmospheres in the metallurgical industries, determination of the efficiency of the liquid-air process of oxygen manufacture, analysis of waste gases from open-hearth furnaces in the steel industry, estimation of oxygen in the atmosphere for the food industry, assessment of the combustion efficiency of glass-melting furnaces, analysis of flue gases in boiler plants, measurement of oxygen content in processes for purifying domestic supplies of coal-gas and in oil refineries and the chemical industry, to name a few. It is expected that many industries which have in the past relied on inferential oxygen analysis (depending on the estimation of the content of other gases) will now adopt direct analysis with the new instrument.



The design of the primary element of the recorder (the analyser) is based on the so-called "magnetic wind" principle, owing its efficacy to the fact that, of the common gases, only oxygen and nitric oxide are attracted by a magnetic field, oxygen more than twice as strongly as nitric oxide. George Kent, Ltd., after five years' intensive research, have taken advantage of modern circuit technique and recent improvements in magnetic and other materials to bring this method to an advanced stage of development and refinement.

To obtain a continuous sample of the gas being analysed, usually a primary refractory filter is inserted at a suitable point in one of the gas passes. The sample is induced through the filter by a water-operated aspirator fitted to the oxygen analyser. The sample gases are carried through pipes to a measuring cell—an annulus with a horizontal glass by-pass tube. This by-pass tube carries on the outside two identical, adjacent platinum windings which are joined in a Wheatstone Bridge circuit and become heated when a voltage is applied across the bridge. One of the windings only is traversed by an intense magnetic field from a large permanent magnet. When the gas sample enters the measuring cell, oxygen is attracted into the by-pass by the magnetic field. As it becomes heated by the winding it loses magnetic susceptibility, is displaced by cool gas, and passes along the by-pass into the annulus. This continuous gas flow, or "magnetic wind," causes differential cooling, and thus differing electrical resistance, in the two windings on the by-pass, unbalancing the bridge. The resulting out-of-balance e.m.f. is measured by a standard Kent "Multelec" potentiometer/recorder and is proportional to the oxygen content of the sample.

Mounted in a small cast aluminium case, the primary unit is neat and compact, easily installed and requires practically no maintenance. All parts of the unit in contact with the gas sample are made of corrosion-resistant materials.

A generous sample of 15 litres per hour is passed through the analyser, which begins to register a change of oxygen content within five seconds of its occurrence and gives a 95% response in 45 seconds. An analyser of this type is sensitive to ambient temperature conditions, which are automatically compensated for by means of a resistance thermometer in a circuit capable of dealing with the range 0°—50° C. The temperature of the gas sample must not exceed 75° C. at the analyser inlet.

The whole instrument is capable of dealing with most of the gas mixtures met with in industrial practice, but to avoid congestion of orders in the early stages, applications are initially being limited to the following ranges:

0— 5% 0—10% 0—15%	oxygen in nitrogen.
0— 2%	oxygen in hydrogen.
0— 2%	oxygen in coal-gas.

The installation is entirely mains-operated, and a constant-voltage transformer is supplied with the equipment to smooth out supply-voltage fluctuations. The primary element (the analyser) can be located at any distance up to 400 yards from the recorder.

George Kent, Ltd., London and Luton.

Spray-Booth Coating

THE laborious process of periodic scraping down to remove paint overspray from the walls of paint spray booths is eliminated by the use of a new "Pyrene" product. "Pultac" is an "easy-peel" material which is applied to the dry walls of the booth by brush or spray gun (50 lb./sq. in.) as supplied, and can be removed at will by simply tearing off. An entirely new formulation containing no nitro-cellulose, "Pultac" is non-inflammable, requires no special equipment or skill to apply (the booth is usable two hours after application), and is resistant to thinners. It is a water-base material and needs no solvent.

The Pyrene Company, Ltd., Metal Finishing Division, Great West Road, Brentford, Middlesex.

CURRENT LITERATURE

Book Notices

SYMPOSIUM ON THE ROLE OF NON-DESTRUCTIVE TESTING IN THE ECONOMICS OF PRODUCTION

164 pp., numerous illustrations, heavy paper cover. American Society for Testing Materials, 1916, Race Street, Philadelphia 3, Pa. $2.50 per copy.

THE six extensive papers and pertinent discussions included in this booklet are frankly aimed at capturing the attention of management and are intended to present unbiased views explaining the actual or potential values of the various well-recognised methods of non-destructive testing in promoting higher quality or more economical production. Sponsored by Committee E–7 on Non-Destructive Testing, American Society for Testing Materials, the Symposium includes contributors who are men of recognised knowledge of the subject in the various fields of testing, and who have had extensive experience in practical applications.

Two general papers are included covering historical background, explanations of the various test methods and generalisation on the types of structural irregularities that could be detected. Three additional papers deal with specific applications of various test methods. The final one includes a general summarisation, correlating the ideas expressed in the previous papers and presenting pertinent views relative to management utilisation.

After an Introduction by H. H. Lester, Watertown Arsenal (Chairman of the Symposium Committee) the six papers and their authors are as follows: *A Basic Guide for Management's Choice of Non-Destructive Tests*—Robert C. McMaster and Samuel A. Wenk, Battelle Memorial Institute; *Discontinuities in Cast and Wrought Products That Can Be Revealed by Non-Destructive Tests*—Kent R. Van Horn, Aluminium Company of America; *The Role of Non-Destructive Testing in the Economics of Casting*—John W. Juppenlatz, Lebanon Steel Foundry; *The Economics and Practical Application of Cobalt 60 in the Radiographic Inspection of Steel Weldments*—W. L. Schwinn, Babcock & Wilcox Co.; *The Economics of Wrought Steel Inspection*—C. D. Moriarty, General Electric Co.; and *Management's Responsibility for Insistence on Non-Destructive Testing in the Development of New Engineering Products and Processes*—L. W. Ball, Naval Ordnance Laboratory.

MANUAL ON QUALITY CONTROL OF MATERIALS

Special Technical Publication 15-C of the American Society of Testing Materials, 1916, Race Street, Philadelphia 3, Pa. 100 pp., heavy paper cover. $1.75 per copy.

A NEW A.S.T.M. Manual on Quality Control of Materials, sponsored by Committee E–11 on Quality Control of Materials, has been issued and takes the place of the widely used A.S.T.M. Manual on Presentation of Data. The new Manual is organized in three parts. Part I essentially covers the presentation of data; Part II presents limits of uncertainty of an observed average; Part III explains the control chart method of analysis and methods for presentation of data.

Part I represents a revision of the main section of the former A.S.T.M. Manual which it replaces. This section discusses the application of statistical methods, other problems of condensing the information contained in a single set of n observations, and presenting essential information in a concise form. Special attention is given to types of data such as would be gathered by individuals or committees and presented to the Society, with emphasis on the variability and the nature of frequency distributions of physical properties of materials.

Part II represents a revision of Supplement A of the old A.S.T.M. Manual which it replaces. In this section is discussed the problem of presenting limits to indicate the uncertainty of the average of a unique sample of n observations. In this part is suggested a form of presentation for use when needed in A.S.T.M. reports and publications; the restricted conditions under which this form is theoretically applied are given and the meaning of such limits is explained, and a table is given to permit ready calculation of 99%, 95%, and 90% "confidence limits" for various sample sizes. Working rules are presented regarding the number of places to be retained in computation and presentation of average, standard deviations, and confidence limits. In this revision the generally accepted term "confidence limit" is introduced, and constants for computing 95% confidence limits are added.

Part III presents formulae, tables, and examples useful in applying the control chart method of analysis and presentation of data as mentioned above. This method requires that the data be obtained from several samples or that the data be capable of subdivision into subgroups on the basis of relevant engineering information. The principles of this part are discussed largely in terms of the quality of materials and manufactured products.

Trade Literature

ONE of the greatest developments in recent years in the welding field has most certainly been inert-gas shielded welding. Developed originally for welding light alloys, particularly magnesium alloys, without the use of a flux, recent years have seen the versatility of the process exploited to the full in its application to a wide range of materials including aluminium, magnesium, copper, nickel and their alloys, stainless steel, lead and precious metals. In "Introducing Argonarc Welding Equipment," recently issued by the British Oxygen Co., Ltd., London, with revised specifications, the process and its applications are discussed, and details are given of the manual and machine welding equipment available for this process.

AN excellent publication emanating from High Duty Alloys, Ltd., Slough, Bucks., deals with extrusions in aluminium alloys as produced at the Company's Distington Works. After an illustrated general introduction, figures are given for the dimensions, weight, area, moments of inertia, moduli of section, radius of gyration, centre of gravity, etc., for the wide range of angles, channels, beams, tees, tubes and miscellaneous sections for which dies are available. Tolerance and conversion tables complete the information apart from Data Sheets

on which are tabulated the properties of aluminium alloy bars, rods, sections and tubes to various general and service specifications, together with the designation of the corresponding commercial product of the leading manufacturers.

In an excellent loose-leaf publication, W. T. Flather, Ltd., Standard Steel Works, Sheffield, describe the products of the Company in general and specific terms with complete cross-reference to standard specifications, normal production limits, etc., so that the designer or engineer, desiring to make a particular component, will be able, by ready reference, to determine the most appropriate steel available, and what is of considerable importance will be able to see the details of the standard limits, sizes and lengths normally produced, and so avoid the additional work and worry of specifications of a "special" rather than a standard product.

Two recent leaflets issued by General Refractories, Ltd., Genefax House, Sheffield, 10, concern Amberlite Insulating Bricks and Amberex Slab and Plastic Insulation, respectively. Four grades of brick are dealt with in the former, having limiting service temperatures of 900° C., 900° C., 1,200° C. and 1,250° C.; three grades of mortar and cement suitable for the three temperatures are also treated. The Amberex products include three grades of slab (1,000° C., 885° C. and 330° C. limiting service temperature), together with three grades of plastic insulation, supplied in dry powder form, and a hard-setting finishing coat for the plastic insulation.

A recently published leaflet concerns the Morgan Crucible Company's newest refractory, M.R.1. The use of selected high quality materials, together with the specialised method of manufacture, has resulted in a product whose chemical structure is entirely different, so that its refractoriness should not be assessed in terms of alumina content. The revolutionary method of manufacture gives a brick which is rigid at a temperature of 1,600° C. Its chemical composition and physical make-up ensure a strong resistance to slag attack and, despite its density, the resistance to thermal shock is of a high order. Copies may be obtained from The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.11.

A reprint of an article by M. Roddan, M.Inst.Pet., M.Inst.F., which appeared in *Metal Treatment and Drop Forging* is available from Shell-Mex & B.P., Ltd., Shell-Mex House, Strand, London, W.C.2. The article, which deals with the Oil Firing of Non-Ferrous Metallurgical Furnaces, is based on a lecture to the South Wales Local Section of the Institute of Metals. A plea for closer attention to fuel consumption and efficiency of burning is made by the author, who describes the types of oil and their important features, as well as some of the various oil-fired furnaces available to the non-ferrous industry.

Those who have the responsibility of selecting and purchasing books for the Work's Library will be interested in a catalogue of suitable books, in many branches of science and technology, which has recently been published by Over's Technical Book Centre, Rugby.

Elcontrol, Ltd., have recently revised and extended their range of standard photo-electric equipment for industrial purposes and the range of available units is described and priced in Data Sheet No. 5. A further Data Sheet, No. 4, dealing with electronic process timers has been revised in the light of recent additions to the range. Copies may be obtained from Elcontrol, Ltd., 10, Wyndham Place, London, W.1.

In the latest publication of Hall-Pickles, Ltd., Port Street, Manchester, 1, an excellent impression is given of the Company's works and products. The approach is mainly pictorial, the text being reduced to the minimum and presented in English, French, Spanish and German, each in its own colour. The photographs show typical applications of Hydra high-speed steels and tools; Hydraloy hard metal tools; Hydra tool steels for hot and cold dies; Hydra stainless and heat-resisting steels; and various heat-resisting alloys in wire and tape form for use in electrical heating equipment.

While primarily designed for marine use, as flooring for engine rooms, deckhouses, wheelhouses, companionways, etc., the Birmetal light-alloy "Hobnail" Pattern Treadplate can be used wherever the normal types of treadplate are used. Full particulars of the properties and standard sizes of this plate are presented in a new leaflet obtainable from Birmetals, Ltd., Woodgate Works, Quinton, Birmingham, 32.

The papers "Metallurgical Considerations of the Gaseous Annealing of Whiteheart Malleable," by Dr. F. Schulte, and "Gaseous Annealing of Malleable Castings: The Present Position," by P. F. Hancock, which were delivered at a British Cast Iron Research Association Conference on Malleable Cast Iron, held in March of this year, are now available in reprint form from Birlec, Ltd., Erdington, Birmingham, 24.

Books Received

"Progress in Metal Physics"—2. Edited by Bruce Chalmers, D.Sc., Ph.D. 213 pp. inc. index. London, 1950, Butterworths Scientific Publications. 45s.

"The Hot Working of Non-Ferrous Metals and Alloys." Institute of Metals Monograph and Report Series No. 9. 208 pp. 1951, Institute of Metals. 15s.

"Engineering Materials Manual." Edited by T. C. Dumond. 386 pp. 1951, Reinhold Publishing Corporation, New York, and Chapman & Hall, London, 36s. net.

"Corrosion Data Survey." Compiled by G. A. Nelson. Engineering Report No. 361, with numerous charts. 1950. Shell Development Company, San Francisco.

"Plastics, Scientific and Technological," 3rd Edn. By H. R. Fleck, M.Sc., F.R.I.C. 414 pp. inc. index. 1951, London, Temple Press, Ltd. 40s. net.

"The Behaviour of Engineering Metals." By H. W. Gillet. 395 pp. inc. index. 1951. John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., London. $6·50 or 36s. net.

"Anuario de la Industria Y Comercio Metallurgicos de Zaragoza." 190 pp. 1950, Zaragoza, Sindicata Provincial del Metal.

"Fourth Empire Mining and Metallurgical Congress," Edited by F. Higham, A.R.S.M., M.Sc., M.I.M.M. Part I, 551 pp.; Part II, 584 pp. London, 1950. Offices of the Congress, 436, Salisbury House, London, E.C.2. 40s. net each part.

"Stainless Iron and Steel." Vol. 1, 3rd Edn. Revised. By J. H. G. Monypenny, F.Inst.P., with a foreword by Professor F. C. Thompson, D.Met., M.Sc. 524 pp. inc. index, and 33 plates. London, 1951. Chapman & Hall, Ltd. 45s. net.

METALLURGICAL DIGEST

Hot Machining of Many Metals Improved by Arc Heating

By E. T. Armstrong and A. S. Cosler

INITIAL experiments established the fact that the machinability of some metals is greatly improved at elevated temperatures and further tests carried out on stainless steel, Vitallium, austenitic manganese steel, high-speed steels and high temperature alloys have given the following results.

The low carbon 20 : 10 chromium-nickel stainless steel submitted to turning tests is a strong and tough material which work hardens as it is deformed during machining. It is machinable at room temperature, but hot machining resulted in a significant improvement in machinability and a greatly increased tool life. At a temperature of 400° F. in this test, the tool life reaches a maximum which is nearly ten times that attained in conventional machining at room temperature. But more surprising were the improvements observed in tests on materials which are essentially unmachinable at room temperature.

Because of the difficulty in machining the cobalt-base, high temperature alloy Vitallium, by conventional methods, it is usually cast to size ; in hot turning tests at 2,000°F., however, this material machined freely, forming long, curling chips. The machined surface was smooth and uniform, and satisfactory tool life was achieved.

At room temperature, austenitic manganese steel consists of metastable austenite and is soft and ductile. The cold working resulting from machining, however, transforms the surface to hard martensite so that it is impractical to machine the steel at room temperature. Under equilibrium conditions the temperature is 1,250° F. above which austenite is in a stable phase and cannot transform to martensite. Hot machining appeared to be the solution and the expected ease of machining at temperatures above 1,250° F. was confirmed in hot-turning and hot-drilling tests.

Hot machining of other alloys, including high temperature alloys, a fully hardened high-speed steel, and a low alloy deep hardening, nickel-chromium molybdenum steel with high manganese content, also resulted in improved machinability.

Heating Methods

Simple heating methods may be used. Manganese steel bucket teeth, for example, can be furnace heated and drilled while hot. In other processes, where it is possible to heat the work throughout, flame heating can be used. For many machining operations, however, it was desirable to have a method which heats only the surface to be machined. With such a method, heating and machining could be accomplished at the same rate and the convenience of hot machining techniques could be made to compare favourably with that of conventional machining practices.

A number of methods were examined but finally, tests were made using arc heating, in which the arc was struck between the work and a carbon electrode. Extremely high power densities were obtained but a number of minor difficulties were encountered. Because cold metal was continually being brought under the carbon electrode, there was a tendency for the arc to be extinguished. To correct this condition a high-frequency, high-voltage spark was superimposed on the arc current. Then, when the arc tended to be extinguished, the core of ionised air produced by the sparks provided a path for continued current flow, allowing the arc to be maintained. The instability of the arc position, caused by the motion of the work under the carbon electrode, was another difficulty. This wandering of the arc produced an unevenly heated surface and prevented uniformity in the machining results. A solution of this problem was found by stabilising the position of the arc by means of a magnetic field. Subsequently arc-heating equipment was developed and applied to the hot-turning tests of many materials.

Effect of Hot Machining

The effect of hot machining on the structure and properties of the work

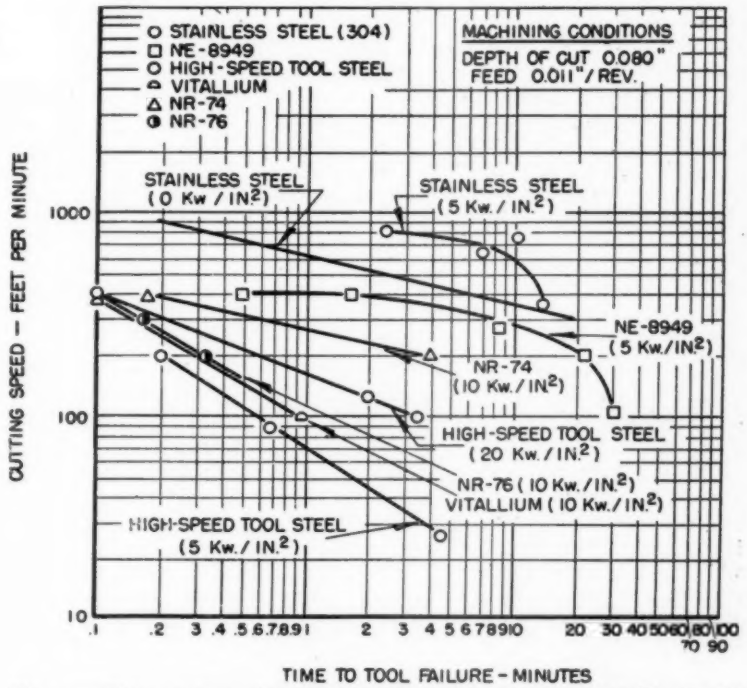

STAINLESS STEEL (304)
NE-8949
HIGH-SPEED TOOL STEEL
VITALLIUM
NR-74
NR-76
MACHINING CONDITIONS
DEPTH OF CUT 0.080"
FEED 0.011"/REV.
STAINLESS STEEL (0 Kw/IN.²)
STAINLESS STEEL (5 Kw./IN.²)
NE-8949 (5 Kw./IN.²)
NR-74 (10 Kw./IN.²)
HIGH-SPEED TOOL STEEL (20 Kw./IN.²)
NR-76 (10 Kw./IN.²)
VITALLIUM (10 Kw./IN.²)
HIGH-SPEED TOOL STEEL (5 Kw./IN.²)
CUTTING SPEED — FEET PER MINUTE
1000
100
10
.1 .2 3 .4 .5 6 7 8 9 1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 80 100 70 90
TIME TO TOOL FAILURE - MINUTES

Fig. 1.—These curves demonstrate the effect of power density on the tool-life/cutting-speed relationship.

From *Materials and Methods*, 1951, **33**, 69-73.

material was considered. The control of structure and hardness consists largely of selecting a power density which will not overheat the work piece in the thin layer just beneath the layer being machined. This was checked by the photomicrographs made before and after hot turning, which showed little change in microstructure whenever heating was done at the appropriate power density. Surface hardness tests also indicated that tempering is minimised during hot turning.

The general effect of hot turning is shown in the tool life cutting speed curves, reproduced in Fig. 1, with the two highest curves representing the data for machining stainless steel. With a constant heating power density of 5 kw./sq.in., a maximum improvement occurs at a cutting speed of 600 ft./min. At this speed the ratio of tool life in hot turning to that in conventional machining is nearly 8 to 1. This ratio approximates 7 to 1 at 800 ft./min. and 2 to 1 at 400 ft./min. No benefit results from hot turning at 330 ft./min. since the two curves intersect at this point.

Tool life in hot machining is also dependent on the tool composition. The compositions of the different carbide tools which were studied for use in hot turning are given as :

	WC	TiC	Co
General finishing	84	10	6
High speed finishing	76	16	8
Low shock finishing	67	25	8

Welding Heat-Treatable Aluminium Alloys

By B. B. Burbank

THE traditional methods of welding aluminium alloys are flame welding, direct metal-arc welding, and carbon-arc welding. These methods require the use of a flux, and for many purposes where corrosion is a serious problem they are not satisfactory. During the last few years great improvements have been made in strength and corrosion resistance by the introduction of two new methods of welding, namely the "Heliarc" and "Aircomatic" processes. These do not require flux materials, as they make use of an inert gas—either helium or argon—to shield the arc. In the Heliarc process an arc is struck and maintained between the work and a pure tungsten electrode, the entire arc being enveloped in a continuous supply of the inert gas. Filler rods are introduced into this shielded arc and melted down to build up the weld bead. This process produces very sound welds, free of inclusions and gas porosity, while the welder has complete control over penetration. Its disadvantages are that it is a relatively slow process, and difficult to use in remote or confined spaces.

The Aircomatic process is basically very similar, but, in place of the tungsten electrode, an aluminium filler rod is automatically fed towards the work, while the arc plays off its end and supplies molten metal to build up the weld bead. The main advantage of the Aircomatic process is its speed of welding, which may be as high as five times that of the Heliarc process. Apart from the saving in time, this results in less heat absorption by the welded parts and hence less distortion. The welds have good appearance and penetration; early difficulties with gas porosity have been largely overome.

The metallurgy of the heat treatment of aluminium alloys is briefly discussed, and the author shows that if the previously heat-treated alloy be welded the physical strength along a marginal zone on each side of the weld is greatly reduced. The extent of the effect depends upon the length of time the welding process holds the surrounding metal at a sufficiently high temperature and is considerably less for the Aircomatic process than for the Heliarc process. Unless the strength can be restored by reheating the entire structure after welding, the fabrication will be weaker in localised areas than the original material. Heat-treatment of welds made with non-heat-treatable filler rods on heat-treatable alloys will not produce the maximum strength, although the blending of the molten base metal with the filler rod will produce a weld which is to some extent sensitive to heat-treatment, according to the amount of weld metal deposited. Although the filler rods most widely used for welding are not heat-treatable, a new compromise filler alloy has been developed and quite extensively used, which is sensitive to heat-treatment and, at the same time, has a comparatively high corrosion resistance.

From *J. Am. Soc. Nav. E.*, **62**, 811, November 1950. (Abstracted in *Brit. Shipbuilding Research Assoc. J.*, **6**, 132, March 1951.)

Effect of Heat-Treatment and Alloying Constituents on the Work-Hardening of Steels

By G. Niebch and A. Pomp

THE hardness characteristics of cold-rolled alloy steels will naturally vary according to the type of heat-treatment previously applied. Some interesting comparative data in this field for a wide variety of low-alloy steels have recently been obtained at the Max-Planck Institute at Aachen.

Specimens were first subjected to three types of heat-treatment (annealing, normalising, and soft-annealing) and then cold-rolled to a 40% reduction in thickness. Parallel tests were performed with an unalloyed steel containing 0·45% carbon. The materials that were thus compared in respect of work-hardening had the following percentage alloying contents: 0·32 C and 1·33 Mn; 0·39 C, 1·54 Mn, and 0·15 V; 0·36 C, 1·22 Mn, and 1·30 Si; 0·35 C and 1·12 Cr; 0·35 C, 1·05 Cr, and 1·02 Mn; 0·47 C, 0·95 Cr, and 0·12 V; 0·26 C, 2·28 Cr, and 0·16 V.

Work-hardening of the individual steels was found to be affected by the different heat-treatments to very diverse extents. In the annealed state all the steels had a lower initial hardness and a lower degree of work-hardening than in the normalised and soft-annealed states. Steels in the annealed state did not exhibit great differences among themselves, whereas very pronounced differences were developed in the normalised specimens. Both the initial hardness and (in particular) the hardness after cold-working were generally highest in the normalised state. No definite correlation could be established between initial hardness and cold-working hardness. Some specimens with differing initial hardnesses increased in hardness to identical extents after cold-working, but others with almost identical initial hardnesses did not increase uniformly in hardness. The change in hardness of normalised and non-annealed material after cold-working was of approximately the same order with the unalloyed steel as well as with steels containing a higher proportion of Mn, but the changes were much greater with the Cr-steels. A comparison of the influence of individual alloying elements revealed the superiority of Cr, which was followed by Mn (quite a marked effect), Mn and Si (much weaker effect), and V (no definite effect).

From *Stahl und Eisen*, 7th December, 1950, **70**, 1166-74.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

AUGUST, 1951 Vol. XLIV, No. 262

Phase-Contrast Metallography*

By E. C. W. Perryman,† M.A., A.I.M. and Mary Lack‡

The phase-contrast microscope is described and its metallurgical application discussed. Examples are given showing the sensitivity of this microscope in revealing small differences in surface level. Reference is made to its use as an aid in solving research problems, and in the interpretation of electron micrographs.

ALTHOUGH the phase-contrast microscope has been used for some considerable time for the examination of transparent objects, its application to the examination of metals and alloys is very recent. The optical principles of phase-contrast microscopy have been fully described in several papers[1, 2, 3] and examples of its use for the examination of metals have been given by Cuckow,[4] Taylor[5] and McLean[6]. This paper is based on experience gained at the British Non-Ferrous Metals Research Association during the last year or more, and it is hoped to indicate some of the directions in which this technique is likely to be useful to the metallographer.

Principles of Phase-Contrast Microscopy

It is well known that image contrasts in the normal metallurgical microscope arise only from differences in colour or reflectivity, or from surfaces which reflect the incident light outside the aperture of the objective. In addition, however, small differences in phase between the light reflected from different parts of a metallic surface arise from small differences in surface level or from variations in the optical properties of the surface. The ordinary metallurgical microscope does not detect these phase differences, but the phase-contrast microscope converts them into differences of intensity in the image of the specimen surface. In fact, the principal value of the phase-contrast microscope is that it is much more sensitive than the ordinary microscope to differences in surface level. According to Habell[7] good contrast is obtained when the differences of level are of the order of one-twentieth the wavelength of light, i.e., about 250 Å,** and differences as little as 50 Å, or about twenty atomic distances, may be detected. Differences in level greater than about 500 Å do not give useful contrast in the phase-contrast image.

Another possible advantage of the phase-contrast microscope is that it may facilitate the differentiation between the various constituents and metallurgical phases present in the specimen even if the surface is optically flat. If these have different refractive indices they will cause phase differences which, as before, are converted into intensity differences in the image.

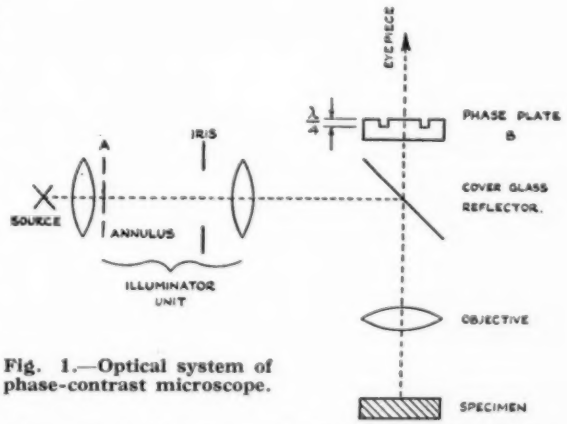


Fig. 1.—Optical system of phase-contrast microscope.

Apparatus

(*a*) *Description of Apparatus*

The differences between the normal and phase-contrast microscopes are twofold, and are as follows:

(1) In the phase-contrast microscope the specimen is illuminated with a hollow cone of light, produced by means of an annular aperture *A* (Fig. 1) in the illuminating system. This annular aperture is removable so that normal or phase-contrast illumination can be used as required.

(2) A special objective lens is used which incorporates the reflector slip and a "phase plate." The latter consists of a glass plate of which an annulus has been so treated that the phase of the light which passes through it is advanced by a quarter of a wavelength ($\lambda/4$) relative to light transmitted by the rest of the plate. When a specimen is placed in position, the light which is directly reflected goes through the annulus in the phase plate *B*, while that which is scattered from the specimen passes through the plain parts of the plate. As a result, a phase difference of $\lambda/4$ is introduced between the direct and scattered light, and this has the effect of converting small phase

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* B.N.F.M.R.A. Report T.M.78P. The work described in this paper was made available to members of the B.N.F.M.R.A. in the confidential *B.N.F. Research Supplement*, June, 1950.

† Investigator, The British Non-Ferrous Metals Research Association, London.

‡ Technical Assistant, The British Non-Ferrous Metals Research Association, London.

** Å = Angström unit (1 Ångström unit = 1×10^{-10} metre).

1 F.I.A.T. Final Report No. 1059.
2 Bitch, G. R. and Stock, J. P. P., *J. Sci. Inst.*, 1942, **19**, 71.
3 Payne, B. O., *J. Sci. Inst.*, 1947, **24**, 163.
4 Cuckow, F. W., *J. Iron and Steel Inst.*, 1949, **161**, 1.
5 Taylor, E. W., *J. Roy. Microscopical Soc.*, 1949, **69**, 49.
6 McLean, D., *Metal Treatment and Drop Forging*, 1951, **18**, 51.
7 Habell, K. J., British Iron and Steel Research Association Report, "A Summary of the Proceedings of the Conference on the Examination of Metals by Optical Methods," 1949, p. 7.

changes in the light reflected from the specimen into intensity differences in the image. The reasons for this conversion are complex and for a full explanation the reader is referred to references 1, 2 and 3. In the Cooke phase-contrast objectives used in the present work, the annulus in the phase plate *B* is designed to advance the phase of the direct light relative to the diffracted light by 90° ($\lambda/4$) and is said to give "positive" phase contrast. This means that high and low areas in the object appear in the image as light and dark areas respectively. To increase the contrast further the annulus in the phase plate is coated with a thin film of metal, so that the intensity of the direct light is reduced, making it more nearly equal to that of the scattered light. Maximum contrast is obtained under these conditions.

(*b*) *Adjustment*

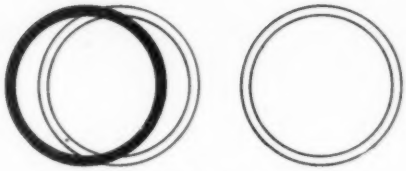
The Vicker's Projection Microscope is set up in the usual way, except that the special illuminator unit, giving a hollow cone of light, is fitted to the instrument in place of the Universal illuminator unit, and the phase-contrast objective is placed on it. A well-polished specimen is placed on the microscope and brought into focus using normal illumination and the appropriate objective. The eyepiece is now replaced by an adjustable auxiliary microscope focused on the phase plate, and the annular aperture *A* (Fig. 1) in the illuminating system brought into its working position. The auxiliary microscope is then adjusted until the brightly illuminated aperture *A* (Fig. 1) is sharply focused and can be seen overlapping the grey ring of the phase plate, as shown in Fig. 2*a*.

The annular aperture *A* (Fig. 1) is then centred by means of two screws until its image is concentric with, and is completely covered by, the annulus in the phase plate (see Fig. 2*b*). If necessary, the condenser in the illuminating unit may be moved to perfect the registration of the annular aperture *A* and phase plate *B*. The system is then in adjustment, and on replacing the auxiliary microscope by the eyepiece, a phase-contrast image is observed. The registration of the two rings (Fig. 2*b*) must be carried out whenever an objective is changed. At present the phase-contrast microscope is rather more troublesome to use than the normal microscope because of the extra adjustments that have to be made. After a little practice, however, these additional adjustments are easily and quickly carried out.

(*c*) *Specimen Preparation.*

Since the phase-contrast microscope is sensitive to small differences in level, it is clear that polishing scratches and other surface imperfections will show up readily. This will be seen in Figs. 3 and 4, which show an unetched galvanized coating polished by means of the diamond dust technique described by Perryman[8] and finally polished on gamma alumina. Besides showing the scratches, the various alloy layers in the coating are revealed, this most likely being due to small level differences between the various layers. In addition to more careful

8 Perryman, E. C. W., *J. Inst. Metals*, 1950, **77**, 61.



(a) **Fig. 2.** (b)

polishing, it is necessary to etch the specimen much more lightly than is usual when using normal illumination. This is shown in Figs. 5 and 6, which show a cast gunmetal lightly etched in 10% ammonium persulphate. From Fig. 5 it will be seen that the etch has not been sufficient to show the cored structure under normal illumination, but is sufficient for phase-contrast. The increase in contrast between the delta phase and the matrix is also apparent, the delta phase being light because it is standing proud of the matrix. Due to this increased contrast, the internal structure of the delta phase is more clearly defined. Heavier etching will reveal the cored structure under the normal microscope, though the contrast between the delta phase and matrix will not be so great as that shown in Fig. 6. Sometimes it is difficult to decide whether the intensity differences in the phase-contrast image are due to differing optical properties or to level differences. This can be checked either by electron microscope examination or by evaporating a silver film on to the specimen surface thereby making the optical properties of the complete surface the same. Tolansky[9] has shown that when silver is evaporated on to a metal surface, the surface contour is taken up by the silver and so the contours present before silvering will be present after. If, therefore, the same phase-contrast image is found after silvering, the intensity differences in the image must be due to level differences and not to differing optical properties. Examination of the gunmetal shown in Fig. 6, after evaporation of a silver film, approximately 800 Å thick, showed the same phase-contrast image (see Fig. 7) as

9 Tolansky, S., "Multiple-Beam Interferometry of Surfaces and Films," 1948, O.U.P.

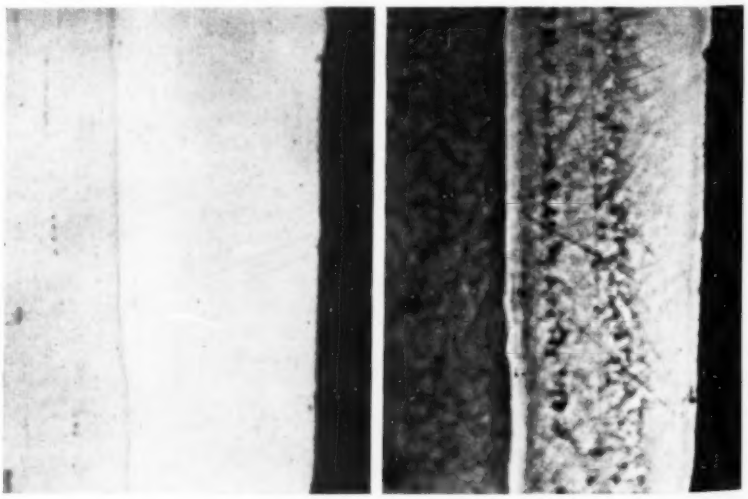


Fig. 3. × 750 **Fig. 4.** × 750

Galvanized coating, as polished. Fig. 3—normal, Fig. 4—phase-contrast.

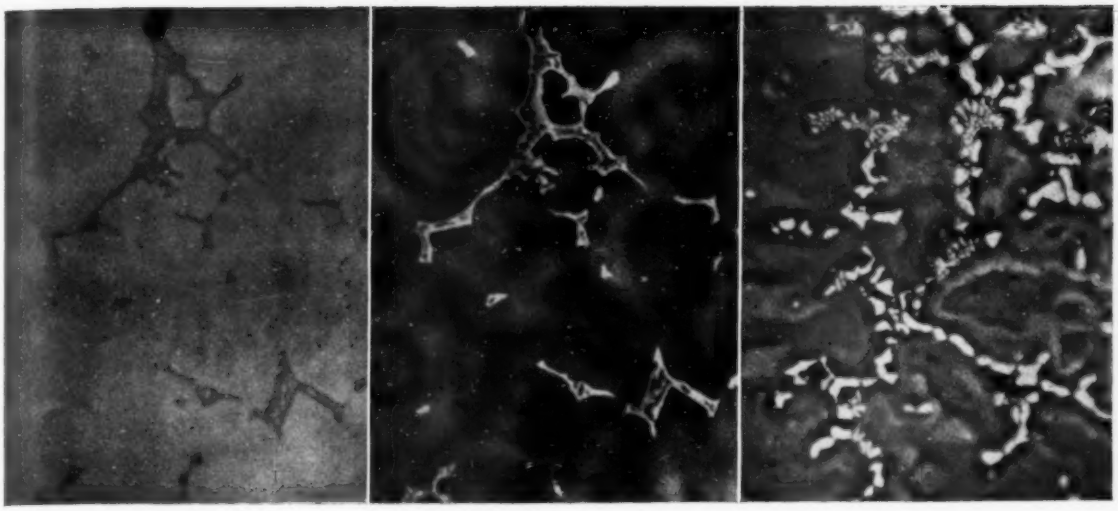


Fig. 5. × 500 **Fig. 6.** × 500 **Fig. 7.** × 500

Cast gunmetal, lightly etched with 10% ammonium persulphate. Fig. 5—normal, Fig. 6—phase-contrast, Fig. 7—phase-contrast, after coating with a silver film.

before silvering. The intensity differences in Fig. 6 must, therefore, be due to level differences produced by unequal polishing and etching.

Results

Electrolytically Polished Surfaces.

Electrolytically polished surfaces of homogeneous specimens are very suitable for examination under the phase-contrast microscope, the slight etching which occurs during polishing being sufficient to reveal the structure. During electrolytic polishing, the rate of attack on the exposed surface of a particular grain varies with the orientation of the grain. With an electrolytically polished polycrystalline specimen, therefore, the grains are at different levels, and hence contrast between the grains is apparent under the phase-contrast microscope. This is illustrated by Figs. 8 and 9 which show specially refined copper, electrolytically polished in 67% orthophosphoric acid, and super-purity aluminium, electrolytically polished in a perchloric acid/alcohol mixture. Under normal illumination no structure could be seen, while under phase-contrast the grain structure is clearly revealed. It is very difficult to reveal the grain structure of super-purity aluminium except by anodising and examination under polarised light, but by using the phase-contrast microscope, the anodising process can be dispensed with, thus saving time in specimen preparation. A commercial purity aluminium —3% magnesium alloy was also examined after electrolytic polishing, and although the grain structure was more apparent under phase-contrast than under normal illumination, it was not sufficiently clear for grain counting.

Fig. 8.—Specially refined copper, electrolytically polished. Phase-contrast. × 300

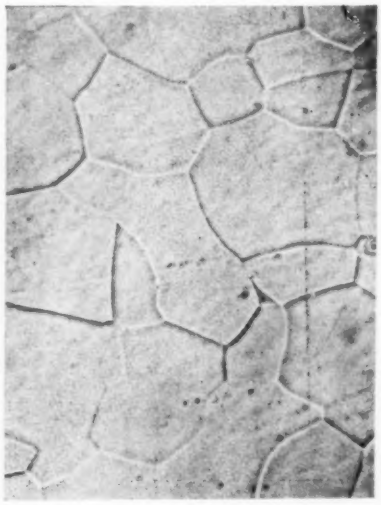


Fig. 9.—Super-purity aluminium, electrolytically polished. Phase-contrast. × 100

There are two points of difference between Figs. 8 and 9 which are worthy of note. There is contrast between the grains in Fig. 8 but not in Fig. 9, presumably because the differences in level between the grains are too great for phase-contrast to operate. In fact, these differences were in this case plainly visible to the unaided eye. The phase-contrast microscope appears to be more sensitive to edge effects than the normal microscope, and because of this the grain boundaries in Fig. 9 are revealed as parallel light and dark bands. Thus, in Fig. 8 the grain structure is revealed by contrast between the different grains, while in Fig. 9 the structure is shown

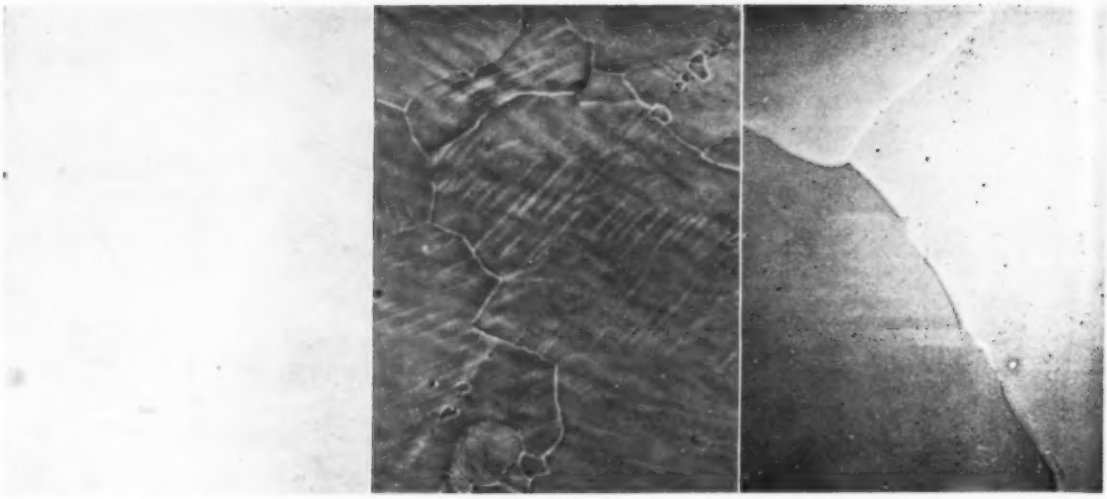


Fig. 10. × 200 Fig. 11. × 200 Fig. 12. × 5,000

High purity zinc, electrolytically polished. Fig. 10—normal, Fig. 11—phase-contrast, Fig. 12—electron micrograph.

by edge effects at the grain boundaries. Figs. 10 and 11 show high purity (99·99%) zinc electrolytically polished in a phosphoric acid/alcohol mixture. As with copper and aluminium, the phase-contrast microscope has revealed the grain structure and, in addition, the twins are clearly seen. That the grain structure was revealed because of differences in level was confirmed by examining a formvar replica under the electron microscope (see Fig. 12), and also by examination of the same specimen after a silver film had been evaporated on to the polished surface. It is interesting to note that it was very difficult to see the twins under the electron microscope, which means that the differences in level between the grains and the twins are of the order of 100 Å.

The grain structure of electrolytically polished zinc can also be revealed by examination under polarised light, but this technique has the disadvantage that the complete structure cannot be seen at any one setting of the analyser. For example, if the analyser is set so that there is good contrast between one grain and its twins, the twins in another grain may not be apparent. In Fig. 11 some of the grain boundaries appear as white lines and others as parallel white and dark lines, and these could be interpreted as indicating the presence of an elevated region or an elevated region bordered by a depressed region respectively (see Figs. 13*a* and 13*b*).

(a) (b)

Fig. 13.—Grain boundary contours in electropolished zinc.

This interpretation was confirmed by the examination of the formvar replica of the electrolytically polished surface under the electron microscope (see Fig. 12).

It is interesting to note that Cuckow[4] found a similar grain boundary contour for copper containing small amounts of bismuth, and McLean[10] for antimonial alpha brass. The high purity zinc shown in Figs. 10, 11 and 12 contained 0·002% lead. Due to the very large size of the lead atom relative to that of zinc, it would be expected to concentrate at places where the lattice fit is poor, i.e., at grain boundaries. It was thought, therefore, that the grain boundary contour shown in Fig. 13 was due to a lead concentration at the grain boundaries, and this view is in keeping with the fact that in the same picture the twin boundaries, where the lattice fit is good, do not show evidence of these elevated regions. Support for this hypothesis was obtained by electrolytic polishing in an aqueous solution of orthophosphoric acid, which is supposed to detect very small amounts of lead in zinc.[11] After polishing, some of the grain boundaries appeared to be attacked preferentially, thus indicating that the grain-boundary structure shown in Figs. 11 and 12 is in some way connected with the lead content.

(*b*) *Structures Containing Transparent Particles*

When studying a structure containing transparent particles under the phase-contrast microscope, great care must be taken in interpretation because (*a*) the refractive index of the particles may play an important part in the formation of the image and (*b*) the incident light is able to penetrate through the particles, thus effectively increasing the difference in level between particle and matrix. Figs. 14 and 15 show an oxygen-bearing copper containing transparent particles of cuprous oxide. It is clear that the small particles in Fig. 15 are reacting to the phase-contrast illumination, but the large ones appear much the same as they do under normal illumination (Fig. 14) except that they are surrounded by a light ring. The fact that the large particles are not reacting to phase-contrast may be due either to penetration of light through the particle, or to the large particles being in greater relief than the small ones after polishing. However, evaporation of a silver film, approximately 800 Å thick, on to the specimen surface caused all the particles, large and small, to be revealed by phase-contrast (see Fig. 16). It appears, therefore, that the large particles were not reacting (see Fig. 15) because of penetration of light through the particle.

10 McLean, D., *J. Inst. Metals*, 1947, **73**, 791.

11 McLean, D., *Nature*, 1946, **158**, 307.

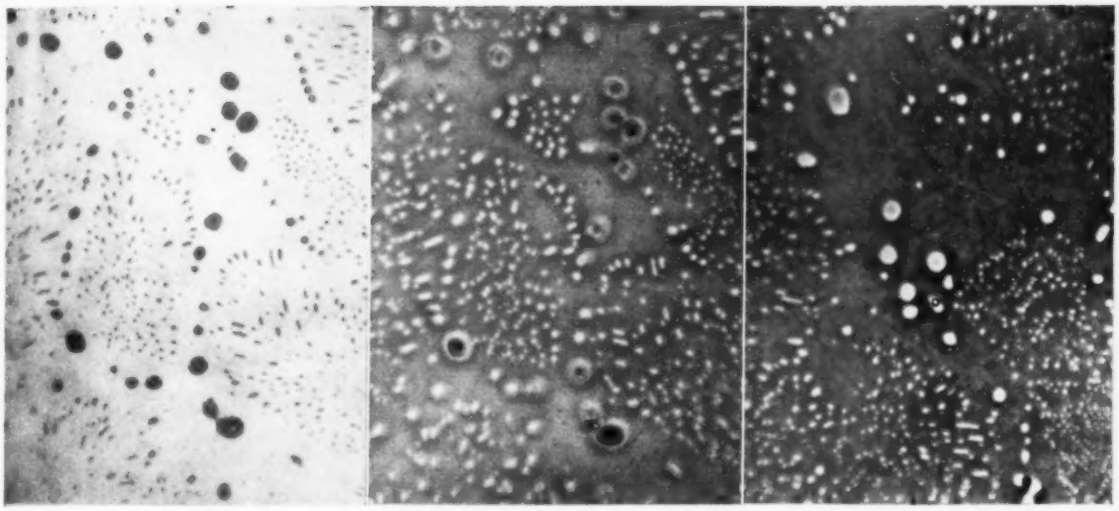


Fig. 14. × 500 **Fig. 15.** × 500 **Fig. 16.** × 500

Cuprous oxide particles in copper. Fig. 14—normal, Fig. 15—phase-contrast, Fig. 16—phase-contrast, after coating with a silver film.

(c) *Other Applications*

The use of the phase-contrast microscope can, in general, be classified under two headings: (i) revealing more detail in a structure, and (ii) help in the interpretation of structures seen under normal illumination. The following results illustrate such uses of the phase-contrast microscope. Figs. 17 and 18 show the structure of an aluminium—7% magnesium alloy, aged at 125° C. for five days after overstraining 10%. This heat treatment has precipitated the beta phase (Mg_2Al_3) both at the grain boundaries and within the grains, and the presence of such precipitate is shown by etching with 10% orthophosphoric acid. In Fig. 18 there are two features which are not apparent under normal illumination: the presence of the light and dark lamellae parallel to the rolling direction, and the tendency of the intergranular precipitate to follow these lamellae. It is possible that these lamellae are due to uneven etching caused by an uneven concentration of magnesium across the section of the rolled sheet.

A rather similar application is the use of phase-contrast for revealing striations in cold-worked material. An annealed alpha brass was mechanically polished and a section at right angles to the mechanically polished surface was electrolytically polished and etched in 10% cuprammonium chloride. The structure of the electrolytically polished and etched section, just below the original mechanically polished surface, is shown in Figs. 19 and 20. While the striations can only just be seen under normal illumination they are very clear under phase-contrast. Similarly slip bands are easier to observe under phase-contrast than under normal illumination. It was observed that the cold work due to the mechanical polishing penetrated to a depth of approximately 500 μ (i.e., 0·05 cm.).

An example of the use of phase-contrast as an aid to interpretation is shown in Figs. 21 and 22. Fig. 21 shows the structure of a copper—5% nickel—1% iron alloy, furnace-cooled from 900°–600° C. and water quenched. It appears that precipitation of a second phase has occurred both at the grain boundaries and within the grains. Examination of this specimen by the electron microscope confirmed the presence of second phase particles, although the amount present was very much less than would appear from Fig. 21. Examination under the phase-contrast microscope (see Fig. 22) confirmed the findings of the electron microscope. The white spots in Fig. 22 represent the precipitated second phase particles, the density of which agrees with that

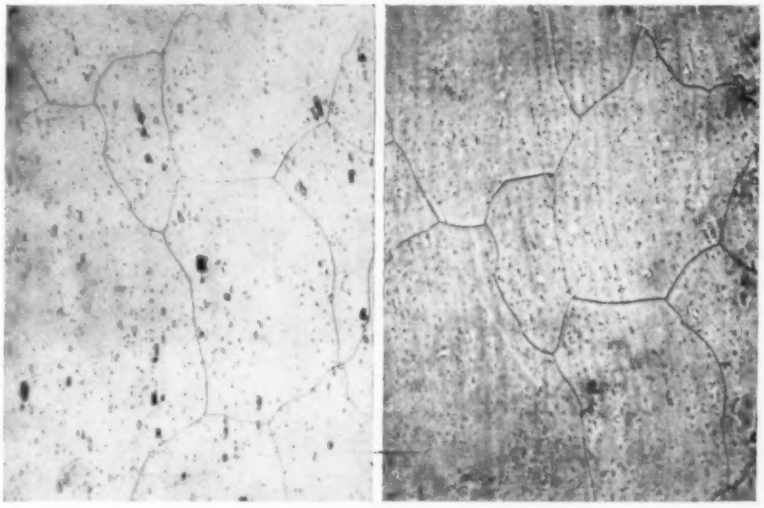


Fig. 17. × 600 **Fig. 18.** × 600

Aluminium—7% magnesium alloy aged at 125° C., etched in 10% orthophosphoric acid. Fig. 17—normal, Fig. 18—phase-contrast.

found by the electron microscope. Closer examination of Fig. 21 shows that the white spots in Fig. 22 correspond to the very dark spots in Fig. 21, while the small black spots (i.e., pits) in Fig. 22 correspond to the lighter spots in Fig. 21. It thus appears that the fine pits in Fig. 22 may represent an early stage in the precipitation process, while the white spots represent the equilibrium second phase. While it is impossible to say from Fig. 21 whether the second phase particles are stained or attacked by the etching, Fig. 22 shows clearly that the particles are stained, because had they been attacked they would have appeared black in this photograph. Two other points worth noting in Fig. 22 are (*a*) the clarity of the grain boundary, the black line indicating that it has been attacked by the etch resulting in a shallow groove, and (*b*) the clarity of the twin plane in the lower part of the photograph, this being revealed because of the difference in level between the twin and the grain.

Fig. 19. × 150

Fig. 20. × 150

Striations in alpha brass, etched in 10% cuprammonium chloride. Fig. 19—normal, Fig. 20—phase-contrast.

Comments on the Use of Phase-Contrast Microscopy

One of the main points arising from these observations is that phase-contrast microscopy reveals very small differences in level, which often leads to information not obtainable by the ordinary light microscope. Besides this, structures containing two or more phases are often met with where there is little contrast between the second phase and the matrix (e.g., second phase particles in copper-base alloys). This lack of contrast sometimes makes it difficult to see the second phase, especially if the particles are small, and moreover increases the photographic difficulties. As these second phase particles are generally of a hardness different from that of the matrix, after polishing there is usually a difference in level between them, so that viewed under the phase-contrast microscope increased contrast is obtained, making the second phase particles easily visible. A similar case is the examination of alloy and electrodeposited coatings. In general, in the as-polished condition there is little if any contrast between the various alloy or electrodeposited layers. Due to the difference in hardness of the various layers, they will, after polishing, be at slightly different levels, and the contrast between them will be increased by the phase-contrast microscope (see Figs. 3 and 4). This may overcome the need for etching, which is generally very difficult, and which often masks the interface between the layers and the substrate due to their generally widely differing electrochemical properties. Against this, there is the fact that differentiation of constituents by colour is not possible under the phase-contrast microscope, because no matter what the colour of the hard constituent is, if it is standing slightly proud of the surface it always appears white. However, once the constituent has been emphasised by examination under phase-contrast, it is often then possible to see the colour under normal illumination. Although it is theoretically possible for the phase-contrast microscope to produce differences in contrast between phases of differing optical properties, no results which can be ascribed to this effect have been encountered in this work. It appears, therefore, that, owing to interpretation difficulties, the phase-contrast microscope will not find much use in the routine examination of metallic

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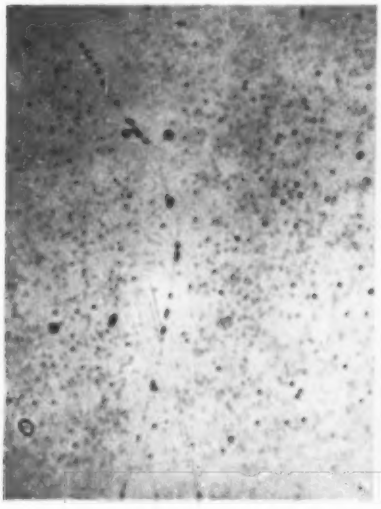

Fig. 21 × 1,500

Fig. 22 × 1,500

Copper—5% nickel—1% iron alloy, furnace cooled from 900° C., etched in 10% ammonium persulphate. Fig. 21—normal, Fig. 22—phase-contrast.

The Production of Sintered Alumina Ware

By T. G. Carruthers, B.Sc., A.R.I.C.*

The techniques used in making sintered alumina, both for laboratory ware and other purposes, often cause difficulty to those with no previous experience in the field. On the other hand, various research laboratories have been in the habit of manufacturing their own alumina bodies for some years past. These laboratories recently prepared papers on their techniques for the Sintered Oxides Sub-Committee (Inter-Service Metallurgical Research Council, Admiralty and Ministry of Supply), and the information gathered is now released in the hope that it may be useful to those desiring guidance. Most emphasis is placed on the slipcasting method in this series of papers published by kind permission of the Chief of the Royal Naval Scientific Service, and the Chief Scientist, Ministry of Supply. This is the third paper of the series.

THE following is an account of the techniques used to produce articles from alumina at Leeds University. Some of the methods used are commonly met with in other branches of ceramics and may, therefore, be familiar to many readers. It is frequently found, however, that it is just these standard operations which give difficulty, since they are not normally described. Some of the methods used have been developed at Leeds, but may nevertheless be in use elsewhere.

Attempts to make sintered alumina were necessitated by the difficulty of obtaining crucibles and tubes readily and by their high price. The slip casting technique has been developed quite empirically, and the finished articles may not, therefore, be of the highest quality which it is believed is ultimately attainable, and may be slightly variable in porosity. For all purposes to which they have been put they have proved completely satisfactory and their production is by no means arduous. The description is divided into four parts : (A) Slip Casting ; (B) Pressing ; (C) Other Methods of Forming ; (D) Firing.

A. SLIP CASTING

Raw Material

The raw material used throughout has been commercial alumina calcined by the makers to 1,200°–1,400° C. This material is known to vary from delivery to delivery, some samples grinding more readily and sintering to high densities at lower temperatures than others, but this has not caused undue inconvenience in the making of ordinary articles.

Grinding

The grinding of the raw alumina has been carried out in two ways.

(*a*) In a mill of manganese steel which was originally designed for the fine grinding of coal under vacuum. This mill is 10 in. diameter and only 2 in. long ; the periphery is shaped to fit the balls. The charge consists of 0·5 Kg. of alumina and six 1½ in. steel ball bearings, the time of grinding varying from 24 to 72 hours, depending on the type of slip required, as detailed later. Typical grain size distribution analyses obtained by measurement with the Andreasen pipette are shown in Table I. The pick-up of iron is relatively small, the alumina coming out slightly grey, but this is in any case removed by acid washing in the preparation of the slip.

(*b*) In an 8 in. diameter rubber-lined mill. The advantages of using this mill are twofold :

(1) Larger amounts of alumina may be ground at once.

TABLE I

Time of Grinding Hours	Steel Mill			Rubber Lined Mill		
	24	48	72	48	96	168
Diameter in Microns	% by weight under size					
10	72	94	99	95	94	95
8	60	88	96	89	89	92
6	42	73	84	77	80	83
5	26	52	67	67	71	76
4	12	25	40	52	57	67
3	5	11	17	34	41	54
2	2	4	7	19	26	34
1	1	1	2	6	11	17

(2) Practically no contamination of the charge takes place from the mill itself and any there is, being organic, readily burns out on firing.

By using alumina balls, acid washing to remove iron might be eliminated. Satisfactory alumina balls have not yet been obtained commercially, and whilst a method of producing high grade balls has been developed, experience in their use is limited. The charge consists of 4 Kg. of alumina with 18 Kg. of tungsten carbide balls graded from ⅜ in. up to 1 in. diameter. By normal standards the mill so used is grossly overcharged, but because of the high density of the balls grinding is very rapid, 48 hours being sufficient in most cases. Some slight contamination with carbide takes place, and this is not entirely removed by acid washing. The discolouration appears to migrate to the surface of the unfired ware, the inside being white, but on firing no discolouration remains. Typical grain size analyses are shown in Table I. Steel balls, which are much cheaper than carbide balls, may be used, but are slower in grinding. Mills of this type are available in sizes up to 4 ft. diameter.

Preparation of Slip

Ground alumina is stirred with cold hydrochloric acid in an earthenware jar, in the proportions of 500 g. alumina to 400 ml. of concentrated hydrochloric acid with 400 ml. water. After stirring for an hour the suspension is allowed to settle for 24 hours, when the supernatant liquor is syphoned off. Water is added to the original level and the mixture again stirred and allowed to settle for 24 hours. This process is repeated twice more by which time the remaining sediment has a density approximately suitable for casting. A reliable indication of when washing is complete is that the supernatant liquid, which in previous washings has been clear and bright though coloured with iron, becomes opalescent. The sediment is adjusted by adding water until it contains about 75–78% by weight of alumina, or, more usually,

* Communication from the Ceramics Division, Department of Coal Gas and Fuel Industries, the University of Leeds.

until it appears to be of the correct consistency. The sediment settling after final washing is usually very dilatant and difficult to stir up with water to adjust to the required consistency for casting. The easiest way has been found to be to transfer it to 1 litre wide-neck screw top jars which are then tumbled for 20 minutes or so in an eccentric tumbler mixer at 60 r.p.m. The slip is de-aerated if high grade ware is required, but this stage is by no means essential if ordinary crucibles, etc., are being cast. De-aeration is done by evacuating for an hour or so in a vacuum dessicator at a pressure of 2 cm. Hg. The slip is stirred and is then ready for use. In our experience no general statement can be made as to whether slips improve or deteriorate with keeping: slips have been used satisfactorily after many weeks storage, others have occasionally been almost useless from the time of making.

Preparation of Moulds

The plaster used for making moulds is commercial "pottery plaster," and the most suitable consistency is obtained by using 300 g. plaster to 200 ml. water. A useful guide to the quantity to mix for a given mould is

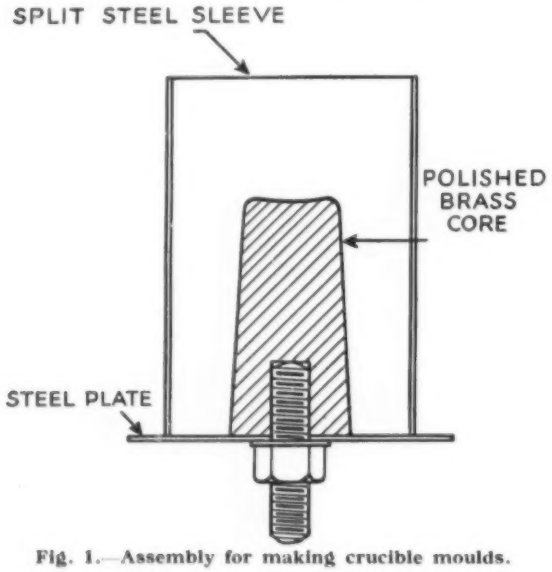

Fig. 1.—Assembly for making crucible moulds.

to use 1 g. plaster per cc. of mould volume. Where amounts of over about 2 lb. of plaster have been used it has been found convenient to mix in a confectionery mixer.

Moulds for making crucibles and tubes are cast in split steel tubes around a polished brass or steel core. The steel tube, which should be well greased before use, stands on a steel plate 9 in. in diameter. The core is held on this plate by a $\frac{1}{4}$ in. bolt. See Fig. 1.

The plaster is poured into the mould so as to flow over the core, and the whole of the core surface is well smeared with plaster, using the fingers, in order to remove entrapped air bubbles. When the sleeve is nearly full the plaster is blunged up and down for a few seconds with a steel rod to raise any further air bubbles, after which plaster is added until it stands proud of the sleeve.

During the time taken to wash out the mixing bowl, etc., the plaster sets hard enough to enable the excess to be cut off neatly with a straight edge. After an hour the bolt is unscrewed and the steel plate removed. A large thick washer is placed round the top of the core and the plate and bolt replaced. Tightening of the bolt then withdraws the core. The sleeve is removed by forcing the seam open with a screwdriver, when the mould will slide out easily. The steel sleeves are rolled out of 20-gauge sheet steel in a range of sizes and depths to leave $1\frac{1}{2}$ to 2 in. thickness of plaster round the core.

Articles which may not be withdrawn straight from the mould because of their shape require split moulds. The technique for making these is best illustrated by examples.

(*a*) *Mould for ball-mill ball* (*Fig.* 2)

A brass or steel disc is bored in the lathe until a ball of the required size (in this case a table-tennis ball was used) will just pass through. The disc is then placed on packings of such a thickness that exactly half the ball protrudes above the disc. A split sleeve is then placed on the disc and plaster poured in until full. When set, the disc is removed, leaving the ball in the half mould. Three conical holes, placed not in an equilateral triangle, are scraped in the flat plaster surrounding the ball. The surface is then coated with a mixture of soap and linseed oil and the split sleeve slid nearly off the mould.

Plaster is poured into the sleeve and when set, the sleeve is removed, the mould opened and the ball taken out. Unless care has been taken to pack the brass disc so as to leave exactly half the ball projecting it will be found that the ball cannot be removed. The three conical holes serve to locate the two halves accurately. The holes for filling the mould are drilled with a $\frac{1}{4}$ in. diameter twist drill whilst the mould is still wet, starting from the inside surface.

(*b*) *Mould for ball-mill jar* (*Fig.* 3)

A strong but easily demountable wooden frame, $1\frac{1}{2}$ in. deeper than the pattern (in this case an existing ball mill pot) and clearing its diameter by 2 in. all round, is constructed. A sheet of stiff cardboard is cut to be a good fit in the frame and in the centre a hole is made, rather smaller than the maximum diameter of the pattern. The pattern is placed upside down in the frame and the cardboard pushed down on to it as far as possible. Plaster is then poured in and made level with the top of the frame. When set the pattern and cardboard are removed and a series of conical holes made in the surface of the plaster which is then coated with linseed oil-soap mixture. The pattern is replaced and, with the plaster at the bottom, the whole of the frame, with the exception of a sector of about one-third, is filled with stiff plastic fireclay. The vertical faces of the fireclay are made flat and square with the pattern, using a spatula, and the sector filled with plaster. When set, the frame is dismantled and the faces of the plaster ground flat on coarse sand paper. The surfaces are painted with oil-soap mixture and the parts reassembled in the frame. Half the fireclay is removed leaving a new sector to fill with plaster. When set the new plaster surface is cleaned up, soaped and replaced and the remaining sector filled with plaster. The whole mould is then dismantled and the lower edge of each segment is chamfered off for about $\frac{3}{8}$ in., the bottom surfaces ground flat, and then reassembled in the frame round the pattern which is turned bottom up. The old plaster base is discarded and a new one cast into the frame on top of the assembled mould. In this way close joints are ensured throughout the mould.

(c) *Mould for solid square bar*

A brass pattern is made and polished. A conical wooden head, with one side square with the base, is screwed on the end to form a riser for the slip. This pattern is laid flat on a sheet of ¼ in. plate glass and surrounded with a sheet aluminium frame. Plaster is poured into the frame until flush with the top. When set, the whole mould is lifted off the glass and the pattern and frame removed. The other half of the mould consists of a flat slab of plaster cast on the glass plate using the frame alone. The two parts are fastened together with a binding of thick string.

All moulds are air dried for a week before use. Where split moulds are used, it is essential to clamp the parts together very securely to prevent differential movement during the pouring out of excess slip.

Casting the Slip

(a) *Crucibles, pots and tubes*

Slip prepared as described above is poured into the mould in a uniform stream, and as quickly as possible, until the slip stands proud of the mould. The slip is quickly stirred in the mould with a glass rod and the thickness of the wall building up is checked continually by placing the rod gently in contact with the side. When thick enough, usually 5–20 seconds, the slip is poured out of the mould, which is then rotated to spread any remaining fluid slip evenly over the wall. After a few minutes the surplus slip standing above the mould can be trimmed off flush using a sharp knife. If thick walled crucibles are being made, more slip has to be added, whilst the wall is forming, to keep the level above the mould top. After standing for from 20 minutes to 2 hours, the longer period for thicker and larger articles, the ware may be removed by dismantling the mould or by inverting and jarring vigorously over a large washer. It will usually be seen at this stage that the ware has very slightly shrunk away from the mould. After removal the ware is air dried for several days, and when dry any flashes from joints in the mould may be readily scraped down with a knife.

(b) *Solid rods*

When casting solid rods a riser is needed above the rod. Slip is poured in uniformly until the mould and riser are full, additions being made to the riser from time to time to prevent a pipe forming in the rod. A thicker slip, of coarser grain size than that used for crucibles, is advantageous to speed up solidification and minimise the amount of topping up which has to be done. When the level of the slip in the riser ceases to fall, no further slip need be added, and after an hour or so the mould may be dismantled and the bar removed.

(c) *Balls*

The two halves of the mould are clamped firmly together and a length of soft rubber tube is inserted into the hole at the bottom until the end is flush with the inside surface. This is important to prevent the slip solidifying in the entrance and blocking it up. A funnel is attached to the other end of the tube and fixed in a retort stand about 4–6 in. above the mould. A second funnel is inserted with a short length of rubber tube into the top hole. The bottom funnel is filled with slip, whilst it is held at a lower level than the mould and then quickly raised and clamped. When slip shows in the upper funnel, a wire is lowered into the mould and worked up and down from time to time to keep the entrance and exit clear. The rubber tube may be worked

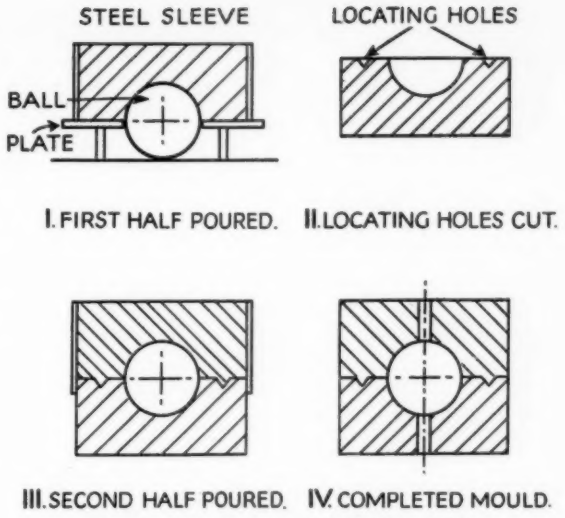

Fig. 2.—Stages in making ball mould.

with the fingers occasionally to ensure that it is clear. As the ball becomes solid, the wire is withdrawn and any further additions of slip may be made through the top funnel with frequent rodding with the wire. When completely solid, the mould is allowed to stand for about 2 hours, after which the rubber tube and funnels are removed and the mould opened. The risers on the ends of the ball are removed with a sharp knife.

B. PRESSING

Many small articles for laboratory use are better made by semi-dry pressing than by slip casting. Whilst many articles produced at Leeds have not been fired to such temperatures nor made from materials fine enough or pure enough to give true sintered bodies, the technique may be of interest to those not familiar with it. Materials which have been most used are " dried slip " crushed

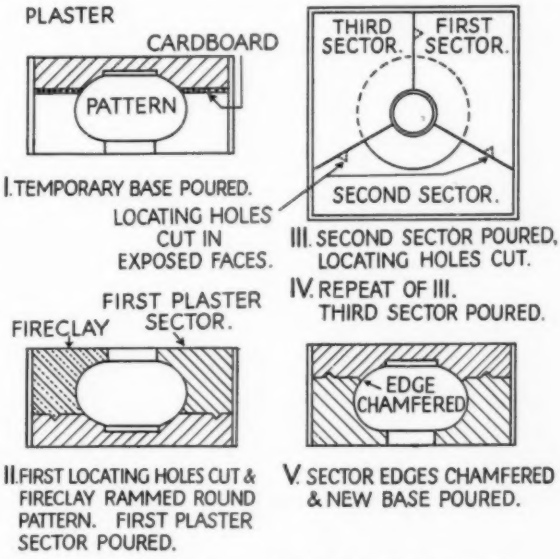
PLASTER
CARDBOARD
PATTERN
I. TEMPORARY BASE POURED.
LOCATING HOLES CUT IN EXPOSED FACES.
THIRD SECTOR.
FIRST SECTOR.
SECOND SECTOR.
III. SECOND SECTOR POURED, LOCATING HOLES CUT.
IV. REPEAT OF III. THIRD SECTOR POURED.
FIRECLAY
FIRST PLASTER SECTOR.
EDGE CHAMFERED
II. FIRST LOCATING HOLES CUT & FIRECLAY RAMMED ROUND PATTERN. FIRST PLASTER SECTOR POURED.
V. SECTOR EDGES CHAMFERED & NEW BASE POURED.

Fig. 3.—Stages in making ball mill jar mould.

up to a fine powder, and coarse and fine proprietary fused alumina cements. These materials are " milled " with 4% by weight of water, using rubber bungs in place of balls. In the case of the coarse material, hand mixing with 1% sulphite lye solution is normally used. The moist material, which usually cakes, is then shredded through 8 and 16 mesh sieves in turn and is then ready for use.

Dies to be used for such materials should be of hardened or case-hardened steel, and should have very small clearances to prevent entry of particles between the plunger and the die wall, otherwise seizure and severe damage to the die will result. It has been found advantageous to lubricate the die and plunger with colloidal graphite in oil, as this increases die life and eases the extraction of the finished part. The pressing technique may best be illustrated by example.

In making 2 in. right-cylindrical blocks, the die is cleaned and lubricated inside with graphite, and the base plug pushed through from the top, leaving a thin smear of lubricant on the die walls. A paper tube, just small enough to go in, is pushed into the die and a weighed amount of the shredded alumina poured in. The die should never be filled to more than three-quarters of its depth. The paper sleeve is then pulled out and any specks of material adhering to the exposed upper die walls removed. After lubricating the plunger, it is pushed in and pressure applied in a hydraulic press, usually to a value of from 5–10 tons/sq. in. The pressure is then released, two bars are placed under the edges of the die and pressure re-applied to push out the die base and the block. For heavy dies, it is much more convenient to turn the die upside down and extract upwards, obviating the danger of the plunger falling through on to the newly extracted block. When thin plates are being made, a sheet of thin paper should be placed on top of the base plug and on the end of the plunger. This may most easily be done by smearing the surfaces with oil and sticking on this a piece of used recorder chart paper. The paper may then be cut accurately to shape by tapping round the sharp corner of the base plug or plunger with a brass rod.

The extracted blocks are strong enough to handle and may be placed in the air oven at 110° C. immediately without harm.

Experience of pressing has been limited to simple shapes such as plates, cylinders, square bars and cylinders with square and tapered holes through them. Where internal holes are formed it is important to radius all square corners to avoid cracking during subsequent firing.

C. OTHER METHODS OF FORMING

Considerable experience has been gained in making special shaped articles of sintered alumina and alumina cement. The procedure usually adopted is to start with an unfired slip cast or pressed article and to cut this to the desired shape with a knife, hack-saw blade or twist drill. When large articles, e.g., 6 × 2 × 2 in. are being made, it is advantageous to work with the block still moist from pressing ; it may be retained in this condition overnight by covering with damp cloths. Any accidental damage may then be made good by moistening the broken surfaces and pressing the parts together again.

When small articles are being made, greater success may be had by working the block after firing to 1,000° C., when the material normally has the hardness and consistency of hard writing chalk.

For use at temperatures up to 1,350° C. and where great strength is not required, articles formed in this way are only fired to about 1,400° C. Especially in the case of alumina cement, a very large increase in hardness and strength takes place without any appreciable shrinkage. This considerably simplifies the making of articles to a given size and minimises cracking of complicated shapes.

Considerable success has recently been obtained in making small specimen holders for differential thermal analysis. These consist of a block containing two cubical holes of 1 cm. side, separated and surrounded by a wall 1 mm. thick. These were made at first by carving them out of a solid block and grinding down the outside walls after firing. They are now slip cast in a plaster mould using metal cores for the holes. These are withdrawn as soon as solidification of the walls has taken place.

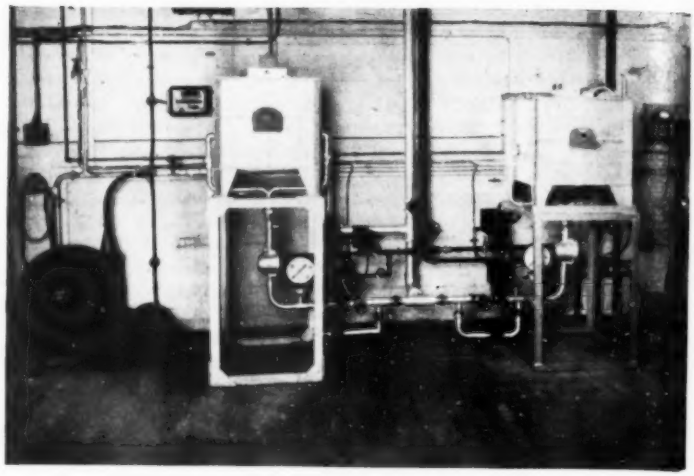

Fig. 4.—Gas-fired sintering furnaces.

D. FIRING

Large fragile articles are always fired slowly to 1,000° C. in an electric muffle before final firing to assist in setting the kiln. For convenience, the furnace is heated up and cooled down under automatic programme control, taking 24 hours. It seems to be important not to expose large ware in this condition to draughts during the cooling stage, especially from red heat to room temperature. Fine hair cracks have been observed when ware was removed from the furnace at 300° C. and allowed to cool quickly in air. The same prefiring procedure is used when machining has to be done before final firing.

Sintering is normally carried out in a commercial gas-fired furnace, two such furnaces being shown in Fig. 4 : the setting space is about 6½ × 5 × 5 in. high. These furnaces, which are lined with hot face insulating brick, may be operated either with a loose muffle or as open fired furnaces. For high temperature firing, they are always used without the muffle, since this gives a larger setting space and a higher temperature. Using

fan-blast air at 1-2 lb./sq. in. and town's gas at 2 in. w.g., the maximum temperature is about 1,730° C. and the gas consumption at top temperature is about 225 cu. ft./hr. As installed at Leeds University, these furnaces may be automatically controlled over the whole of their temperature range. The control system consists of a Pt/Pt 13% Rh thermocouple, or a total radiation pyrometer, connected to a potentiometric controller which operates solenoid valves in the gas and air lines to the mixer on the furnace. Hand-operated by-pass valves are provided for setting the minimum fuel input and for manual operation of the furnace during the heating-up period. The radiation pyrometer is mounted on a pivoted bracket (not shown in the photograph) in front of the furnace, and is sighted through a hole 1 in. dia. in the door block. Although this instrument requires a hole at least 2 in. dia. to give its calibrated reading, a sufficiently large output is obtained for control purposes. The actual furnace temperature is measured independently, with a disappearing-filament pyrometer, through the same hole in the door.

The small heat capacity of these furnaces makes it very difficult to obtain a slow and uniform heating rate as the temperature tends to rise very rapidly each time the fuel input is increased. For this reason the firing schedule used is rather short and it is thought that this is the reason why large articles and thick sections are difficult to fire without severe cracking. In a normal run, a temperature of 800° C. is reached in about 2–2½ hours and thereafter as smooth a rise as possible is maintained up to 1,600° C. in a further 4–5 hours. It is considered that the temperature range in which as slow a rise as possible should be maintained is between 1,350° and 1,650° C., since the rate of shrinkage increases very rapidly with temperature in this range. If the heating rate is too rapid, with the consequent production of marked temperature gradients, a widely differing series of shrinkage rates will be set up in the ware. This undoubtedly leads to severe cracking. Once above 1,650° C., most of the shrinkage has taken place and this problem is not then so serious; in any case, the rate of temperature rise in most gas-fired furnaces is fairly slow above this temperature. For ordinary use, no attempt is made to fire the ware above 1,700° C., but this temperature is usually maintained for 1–2 hours. The furnace is cooled down as uniformly as possible to about 1,100° C. in about 2 hours, at which stage the air and gas supplies are turned off completely and the remaining cooling to room temperature takes place overnight.

When setting the kiln, the ware is supported on a layer of loose alumina powder at least ¼ in. thick. This is scraped off the hearth and renewed before each firing so as to keep it loose. Large articles are placed in the middle of the hearth and surrounded by smaller ware so as to minimise flame impingement. Small crucibles may be fired standing inside larger ones without undue danger of cracking the larger one. If a few small articles are to be fired, they are normally covered with inverted crucibles or short lengths of tube, and the whole of the spare setting space filled with other scrap alumina ware. This enables a higher temperature to be obtained and produces a more uniform temperature distribution.

Tubes are normally made with a bottom on and fired as crucibles standing upright. After firing, the bottom is cut off using a diamond impregnated slitting disc, which is the only satisfactory means of cutting sintered alumina. The very long life of these discs amply offsets the high initial cost. Surface grinding wheels and drills are also available, and are invaluable for working hard materials of this type.

Conclusion

Alumina ware which is completely satisfactory for normal high temperature work can be prepared by the above methods. A detailed account has been given in the hope that those just starting work may be helped over problems which otherwise have to be solved by tedious trial and error. A comparison of the methods in use by different workers will help considerably in deciding which are the important stages in the process and in eliminating those which are unnecessary complications.

Former Ambassador Joins Nickel Board

THE International Nickel Co. of Canada, Ltd., announce the election to the Board, of The Honourable Lewis W. Douglas, former American Ambassador to the Court of St. James, and Mr. I. C. Raymond Atkin, Vice-President, Director and Member of the Executive Committee of J. P. Morgan & Co. Inc.

Born in Arizona of Canadian Ancestry, Mr. Douglas was at one time a Member of the Arizona House of Representatives and subsequently of the United States Congress. Mr. Douglas had been engaged in mining and general business in Arizona. Later he became Vice-President and a Member of the Board of Directors of the American Cyanamid Co. and Principal and Vice-Chancellor of McGill University, Montreal. He is probably best known in this country as American Ambassador to the Court of St. James from March, 1947 to November, 1950.

Mr. I. C. Raymond Atkin was born in Ontario, Canada, and saw distinguished service in the Canadian Army in World War I. A former President of the Canadian Society of New York, he was with the Royal Bank of Canada prior to joining J. P. Morgan & Co. in 1925.

A Director of Canada Life Assurance Co. and Johns Manville Corporation, Mr. Atkin is Chairman of the Foreign Exchange Committee of the New York Money Market.

Acetylene Association Jubilee

THE British Acetylene Association celebrated the Jubilee anniversary of its foundation by a series of meetings and functions in London from July 12th to 14th. As a part of the celebrations, the Association acted as host to a meeting of La Commission Permanente Internationale de l'Acétylène. The countries thus represented were Austria, Belgium, Denmark, Eire, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United States.

Technical meetings were held at the Connaught Rooms throughout Thursday, and Friday, July 12/13th, and the proceedings concluded with a Banquet and Dance at the Café Royal on the Friday evening, except for a visit to the House of Commons on the Saturday morning, the principal object of which was to inspect the heating and ventilating installation, said to contain a larger number of gas welds than is to be found elsewhere in the same area.

The Study of Dusts in Industrial Atmospheres

6—Photoelectric Apparatus and Apparatus for the Collection of Large Samples

By P. F. Holt, B.Sc., Ph.D., D.I.C., F.R.I.C.

In this concluding article of the series, the author discusses the photoelectric methods of obtaining instantaneous readings which are a measure of the dustiness of the atmosphere, and concludes with a description of apparatus for the collection of large samples for fundamental research purposes.

THE methods of dust collection which have been described in earlier articles are designed to give a more or less accurate picture either of the mass concentration of the dust over a sampling period of minutes or hours, or a figure for particle count during a period of seconds or minutes. In every case, the field sample must be evaluated in the laboratory later, and this may take some hours. Using the methods so far described, it is seldom possible to obtain dust concentration figures until the day following that on which the samples were taken.

To facilitate dust control, it would be of the greatest value if counts and mass concentration figures could be obtained immediately, whenever they were required. Average mass concentration figures over a shift are easy to obtain, but average figures for particle counts require the evaluation of a large number of samples, a tedious and time-consuming procedure. A simple method of obtaining these values is urgently needed.

Photoelectric Methods

Whilst it is not yet possible to obtain immediately either counts or mass values, a considerable amount of effort has gone into the design of instruments which measure photo-electrically the absorption or reflection of light by dust particles, and can give an instantaneous value which is related indirectly, and in a rather complex manner, to the dustiness of the atmosphere.

The earliest instrument of this type interposed a sample of the dust-laden air between a light source and a photoelectric cell. Absorption of light by the dust particles produces a decrease in the e.m.f. induced in the cell. The new e.m.f. can be measured by a sensitive milliameter and the decrease in the current is proportional to the dust concentration. This type of instrument suffers from the serious defect that, since the amount of light absorbed depends very largely on the colour of the dust and on the texture of its surface, transparent particles transmitting much of the light which strikes them, the apparent dust concentration will also depend on the type of dust investigated. Another disadvantage of the method is that the apparatus is relatively insensitive when the dust concentration is small.

A much more satisfactory type of instrument utilises the Tyndall effect. When a beam of light passes through a dusty atmosphere the particles of dust scatter the light, and these instruments are designed to ensure that a part of the scattered light falls on to a photoelectric cell positioned at right angles to the main beam. The e.m.f.

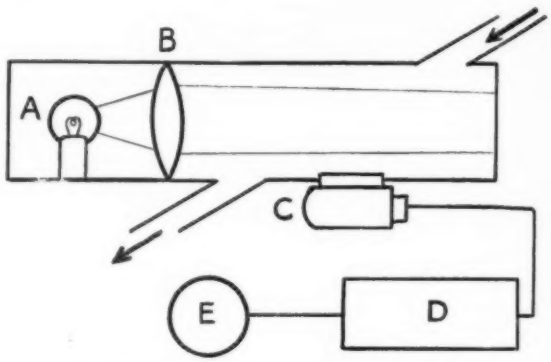

Fig. 1.—Diagram of photoelectric dust meter. The direction of the flow of air is shown by the arrows.

produced in the cell is stepped up by the aid of multipliers and is measured by a milliameter: a recording meter may be used. Fig. 1 shows a diagram illustrating the principle of these instruments. The values given by this type of dust meter are much less affected by the nature of the dust than are those obtained by instruments which rely on the direct absorption of light by the dust particles, but because the amount of light involved is very much smaller, the apparatus is necessarily much more complicated, bulky and expensive.

The intensity of the reflected light is a complicated function depending on the number of particles in the atmosphere, their size, their nature (in particular, their refractive index) and other factors. It will be seen that the Tyndallometer readings cannot be translated into particle counts or into mass concentration values. Provided that the type of dust and size grading is reasonably constant, the Tyndallometer values do vary in a similar manner to the counts and mass concentration figures, however. Whilst this type of instrument cannot yet be used for absolute measurements, the advantages of being able to take instantaneous readings, the ability to obtain continuous records of the dust concentrations throughout an entire working shift, and the fact that centralised recorders may indicate dust concentrations in a laboratory or office remote from the dust-producing operation, indicate that there are great possibilities for this type of instrument in the field of dust control.

A very simple type of apparatus for estimating dust

Fig. 2.—Densitometer for assessing the depth of deposit on filter paper samples.

concentrations on the spot has been developed by H. H. Watson for use in collieries. A measured sample of air is drawn through filter paper by means of a hand pump. The dust deposited in the paper increases its opacity and the change in this value is measured by a photoelectric method. An instrument, made specifically for carrying out these measurements, is now made commercially and is shown in Fig. 2.

Watson states that the relation between the optical density of the stain made on the filter paper by the dust and the number of particles producing the stain is given by the equation :

$$Q = aD^b$$

in which Q is the number of particles, D is the optical density and a and b are constants. The value of b has been determined experimentally as 1·5, whilst the factor a depends on the physical characteristics of the dust and particularly on its size distribution. The instrument is calibrated for the particular dust which is to be investigated against a thermal precipitator.

The Collection of Massive Dust Samples

Large samples of dust are usually required only when fundamental research is to be carried out into the nature and properties of a dust cloud. For this purpose it is essential to obtain a sample which is truly representative of the air-borne dust. No segregation is permissible, either with respect to particle size or to composition. The apparatus which is suitable for this purpose varies considerably with the concentration of the dust cloud to be handled. One of the earliest methods used for the collection of samples large enough for analysis was to draw large volumes of air through filter paper. With many dusts filter paper clogs rapidly, however, and the method was largely discarded, but it has been revived recently for the separation of air-borne beryllia dusts, which have received considerable attention because of their ability to produce pulmonary disease. Beryllia is seldom present in industrial atmospheres in concentrations larger than a fraction of a

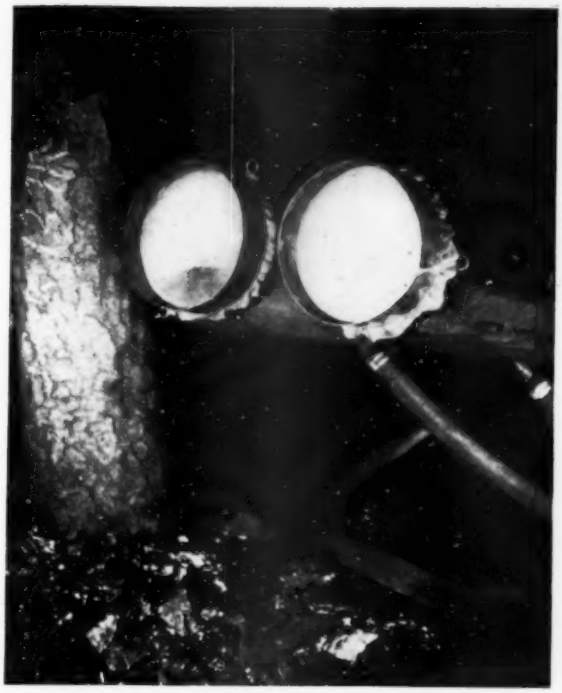

Fig. 3.—Fabric filter installed at the coal face.

milligram per cubic metre, and very large samples of air must be filtered to obtain samples of dust large enough to be handled in the laboratory. The air is drawn at high velocity through a large diameter filter paper which is later ignited to recover the dust.

When the dust present in the air has a mass concentration of the order of a few milligrams per cubic metre, the salicylic acid filter, which was described in an earlier article is the most convenient method available for the collection of sizeable samples ; it is now in general use for this purpose. It is simple to handle, it collects all

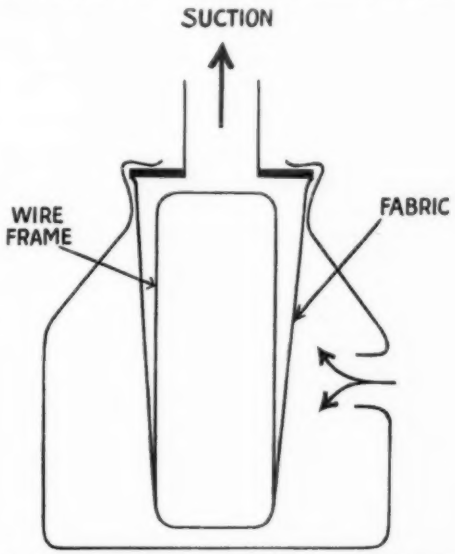

Fig. 4.—Diagram of another type of cloth filter.

the dust and the filter can be run for an indefinite period without disintegration.

For very heavy concentrations of dust, such as those encountered in collieries, sampling is best carried out through finely woven fabric. This may be stretched over a gauze which covers the mouth of a large metal funnel. Filters of this type, set up in a colliery working, are shown in Fig. 3. Another design, which is very convenient when sampling is to continue for several days, is that illustrated in Fig. 4. It is adapted from the design of the "Tellus" vacuum cleaner. A bag made from finely woven poplin fabric is stretched over a wire frame

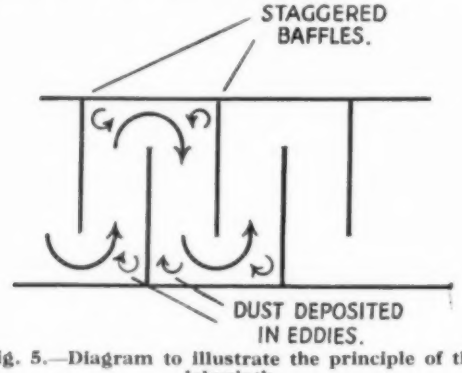

Fig. 5.—Diagram to illustrate the principle of the labyrinth.

held inside an aluminium container, and a source of suction is connected to the inside of the bag so that the dust collects on the outer side. If the suction is turned off, the dust either remains attached to the fabric or it falls off into the container.

One other method of collecting large samples which is eminently successful when handling certain dusts, such as cement, but is much less efficient when sampling some other dusts, is the labyrinth. The principle of this instrument is illustrated in Fig. 5. The air is drawn at high velocity through a tube in which a series of baffles are fixed in such a manner that the air stream is constantly forced to change its direction. Near the edges of the baffles eddy currents are set up which throw out the dust centrifugally.

Phase-Contrast Metallography—*continued from Page 102*

specimens, but should provide a powerful additional tool to the research worker.

The phase-contrast microscope is comparable with the electron microscope in that it is possible to decide whether some structural feature is above or below the general surface level, though, of course, its resolving power is no better than the normal light microscope and very inferior to that of the electron microscope. The fact that the phase-contrast microscope can detect small changes in surface contour should facilitate the development of suitable etching techniques for electron microscopy, and in this respect the instrument should be a valuable complement to the electron microscope. Furthermore, electron micrographs prepared by a replica technique cannot always be interpreted unambiguously because the contour of the free surface of the replica is not known. The phase-contrast microscope, not having this difficulty to contend with, should thus help in the interpretation of electron micrographs.

Acknowledgments

The authors thank the Director and Council of The British Non-Ferrous Metals Research Association for permission to publish this paper.

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